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(12) **United States Patent**
Reddy et al.

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(45) **Date of Patent: Aug. 23, 2022**

(54) **SYSTEM AND METHOD FOR PREDICTING THE IMPACT OF SOURCE CODE MODIFICATION BASED ON HISTORICAL SOURCE CODE MODIFICATIONS**

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(73) Assignee: **CERNER INNOVATION, INC.**, North Kansas City, MO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/101,284**

(22) Filed: **Nov. 23, 2020**

(65) **Prior Publication Data**

US 2022/0164181 A1 May 26, 2022

(51) **Int. Cl.**

G06F 8/71	(2018.01)
G06F 8/75	(2018.01)
G06N 20/00	(2019.01)

(52) **U.S. Cl.**

CPC ***G06F 8/71*** (2013.01); ***G06F 8/75*** (2013.01); ***G06N 20/00*** (2019.01)

(58) **Field of Classification Search**

CPC G06F 8/71; G06F 8/75; G06N 20/00

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,936,634	A	8/1999	Kawamoto et al.	
8,898,676	B2 *	11/2014	Hiltgen	G06F 9/45558 718/106
9,122,490	B2 *	9/2015	Fanning	G06F 8/75
10,275,240	B2 *	4/2019	Kogan	G06F 8/77
10,817,283	B1 *	10/2020	Naik	G06Q 10/103
11,106,460	B2 *	8/2021	Culibrk	G06F 8/71
2009/0083268	A1 *	3/2009	Coqueret	G06F 8/71
2010/0299305	A1 *	11/2010	Laxman	G06F 8/71 707/805

(Continued)

OTHER PUBLICATIONS

Notice of Allowance received for U.S. Appl. No. 17/101,287, dated Aug. 23, 2021, 10 pages.

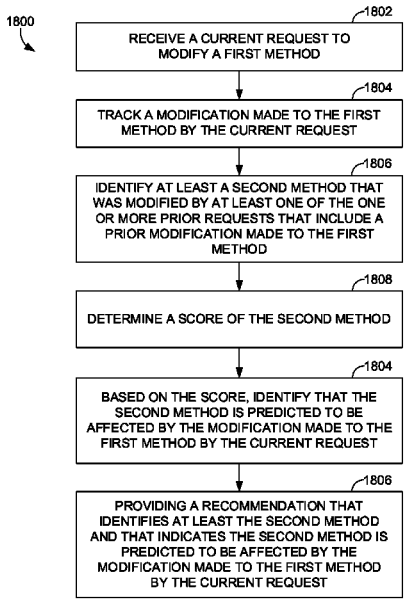
Primary Examiner — Douglas M Slachta

(74) *Attorney, Agent, or Firm* — Shook, Hardy & Bacon L.L.P.

(57) **ABSTRACT**

Methods, systems, and computer-readable media are disclosed herein that utilizes historical changes made to files and methods in computer programming code to predict related files and methods that may be affected by current and/or future changes made to other files and methods. In aspects, when computer code for a particular method is going to be edited, other methods are identified that were changed in previous editing sessions that also included changes to the particular method. Using scoring techniques for the other methods, a recommendation is provided that details the relative strength of whether the other methods are predicted to be affected by any changes made to the computer code for the particular method that is edited.

15 Claims, 23 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0036497	A1*	2/2012	Karthik	G06F 8/71 717/122
2012/0311523	A1*	12/2012	Venkataraman	G06F 16/289 717/104
2013/0080993	A1	3/2013	Stravers et al.	
2013/0227542	A1*	8/2013	Pei	G06F 8/71 717/170
2014/0310559	A1	10/2014	Deng et al.	
2014/0331203	A1*	11/2014	Elshishiny	G06F 11/3676 717/124
2016/0188325	A1*	6/2016	Blitzstein	G06F 8/71 717/101
2017/0068676	A1	3/2017	Jayachandran et al.	
2020/0034135	A1*	1/2020	Shi	G06N 5/04
2020/0174907	A1*	6/2020	Lundquist	G06F 11/3604
2020/0349055	A1*	11/2020	Reddy	G06F 8/71
2021/0049050	A1	2/2021	Goodwin et al.	
2021/0049465	A1	2/2021	Bogdan et al.	
2021/0247976	A1*	8/2021	Masis	G06F 8/71

* cited by examiner

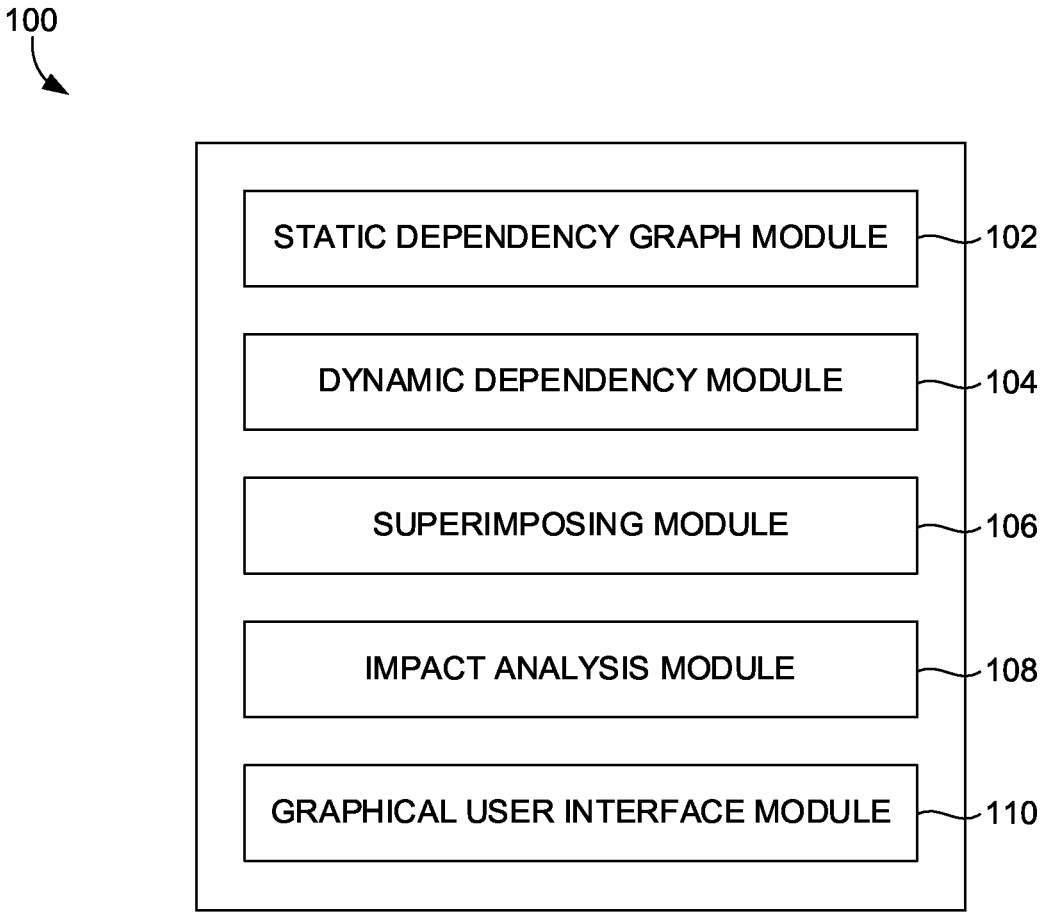

100
STATIC DEPENDENCY GRAPH MODULE
102
DYNAMIC DEPENDENCY MODULE
104
SUPERIMPOSING MODULE
106
IMPACT ANALYSIS MODULE
108
GRAPHICAL USER INTERFACE MODULE
110

FIG. 1.

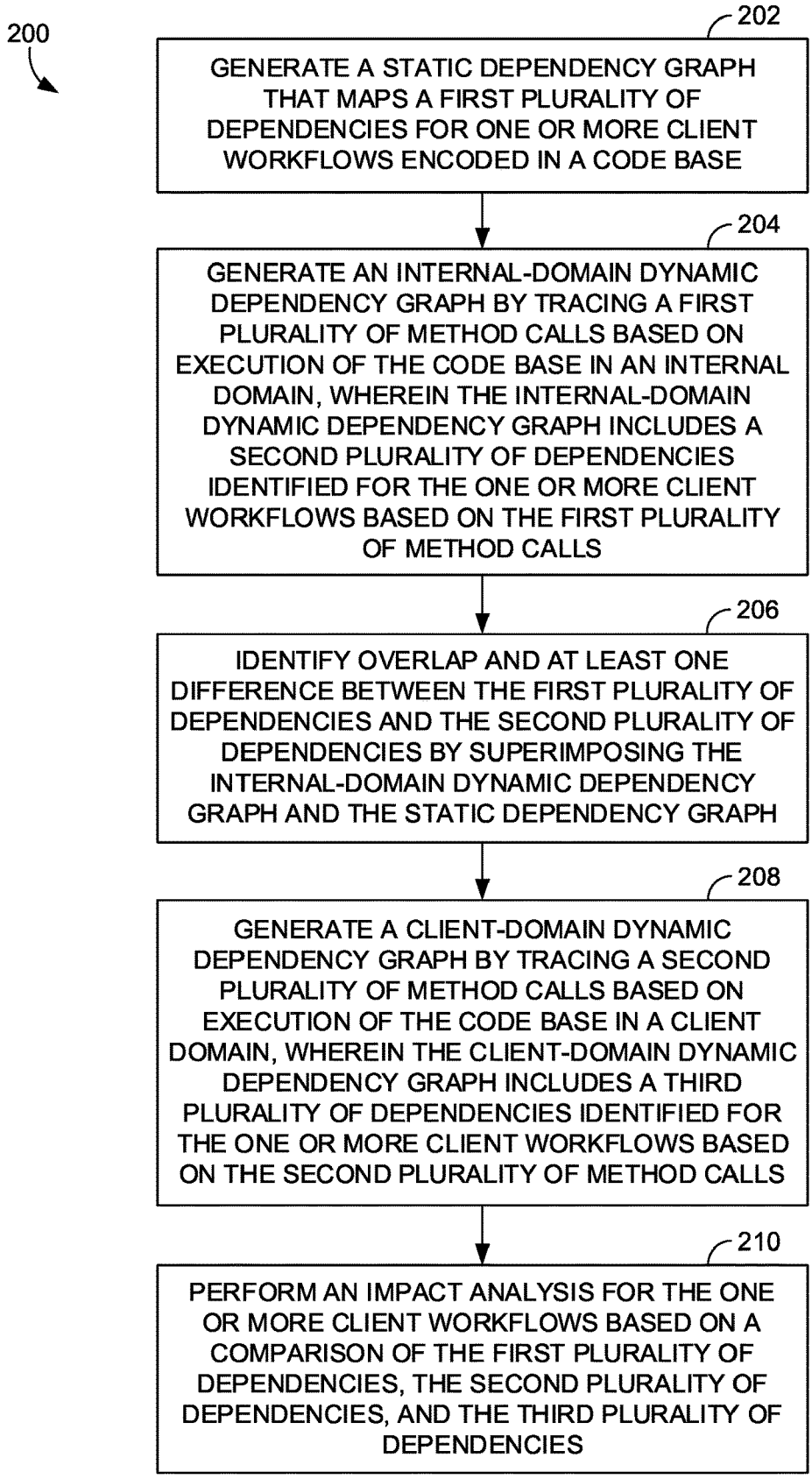

200
202
GENERATE A STATIC DEPENDENCY GRAPH THAT MAPS A FIRST PLURALITY OF DEPENDENCIES FOR ONE OR MORE CLIENT WORKFLOWS ENCODED IN A CODE BASE
204
GENERATE AN INTERNAL-DOMAIN DYNAMIC DEPENDENCY GRAPH BY TRACING A FIRST PLURALITY OF METHOD CALLS BASED ON EXECUTION OF THE CODE BASE IN AN INTERNAL DOMAIN, WHEREIN THE INTERNAL-DOMAIN DYNAMIC DEPENDENCY GRAPH INCLUDES A SECOND PLURALITY OF DEPENDENCIES IDENTIFIED FOR THE ONE OR MORE CLIENT WORKFLOWS BASED ON THE FIRST PLURALITY OF METHOD CALLS
206
IDENTIFY OVERLAP AND AT LEAST ONE DIFFERENCE BETWEEN THE FIRST PLURALITY OF DEPENDENCIES AND THE SECOND PLURALITY OF DEPENDENCIES BY SUPERIMPOSING THE INTERNAL-DOMAIN DYNAMIC DEPENDENCY GRAPH AND THE STATIC DEPENDENCY GRAPH
208
GENERATE A CLIENT-DOMAIN DYNAMIC DEPENDENCY GRAPH BY TRACING A SECOND PLURALITY OF METHOD CALLS BASED ON EXECUTION OF THE CODE BASE IN A CLIENT DOMAIN, WHEREIN THE CLIENT-DOMAIN DYNAMIC DEPENDENCY GRAPH INCLUDES A THIRD PLURALITY OF DEPENDENCIES IDENTIFIED FOR THE ONE OR MORE CLIENT WORKFLOWS BASED ON THE SECOND PLURALITY OF METHOD CALLS
210
PERFORM AN IMPACT ANALYSIS FOR THE ONE OR MORE CLIENT WORKFLOWS BASED ON A COMPARISON OF THE FIRST PLURALITY OF DEPENDENCIES, THE SECOND PLURALITY OF DEPENDENCIES, AND THE THIRD PLURALITY OF DEPENDENCIES

FIG. 2.

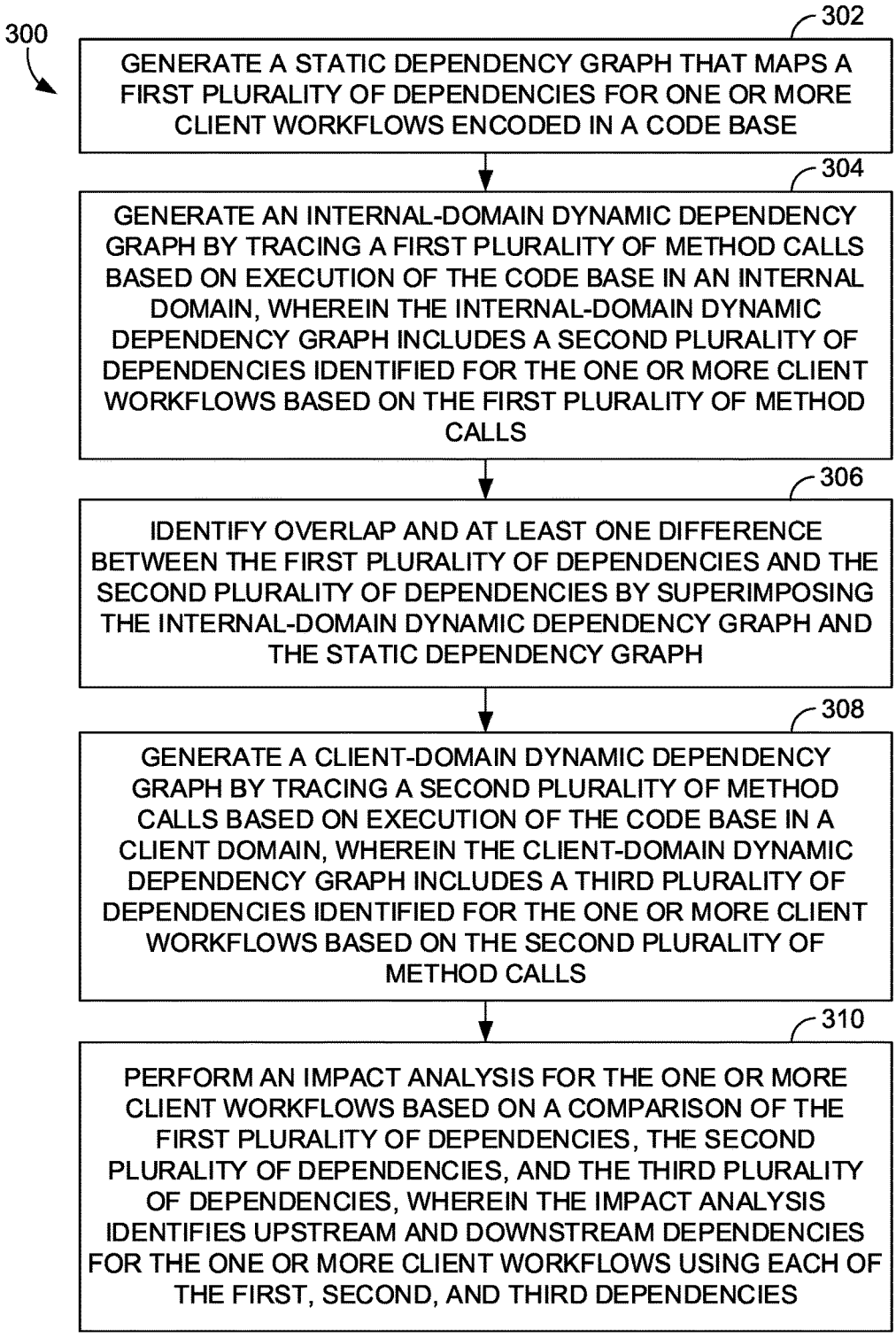

300
302
GENERATE A STATIC DEPENDENCY GRAPH THAT MAPS A FIRST PLURALITY OF DEPENDENCIES FOR ONE OR MORE CLIENT WORKFLOWS ENCODED IN A CODE BASE
304
GENERATE AN INTERNAL-DOMAIN DYNAMIC DEPENDENCY GRAPH BY TRACING A FIRST PLURALITY OF METHOD CALLS BASED ON EXECUTION OF THE CODE BASE IN AN INTERNAL DOMAIN, WHEREIN THE INTERNAL-DOMAIN DYNAMIC DEPENDENCY GRAPH INCLUDES A SECOND PLURALITY OF DEPENDENCIES IDENTIFIED FOR THE ONE OR MORE CLIENT WORKFLOWS BASED ON THE FIRST PLURALITY OF METHOD CALLS
306
IDENTIFY OVERLAP AND AT LEAST ONE DIFFERENCE BETWEEN THE FIRST PLURALITY OF DEPENDENCIES AND THE SECOND PLURALITY OF DEPENDENCIES BY SUPERIMPOSING THE INTERNAL-DOMAIN DYNAMIC DEPENDENCY GRAPH AND THE STATIC DEPENDENCY GRAPH
308
GENERATE A CLIENT-DOMAIN DYNAMIC DEPENDENCY GRAPH BY TRACING A SECOND PLURALITY OF METHOD CALLS BASED ON EXECUTION OF THE CODE BASE IN A CLIENT DOMAIN, WHEREIN THE CLIENT-DOMAIN DYNAMIC DEPENDENCY GRAPH INCLUDES A THIRD PLURALITY OF DEPENDENCIES IDENTIFIED FOR THE ONE OR MORE CLIENT WORKFLOWS BASED ON THE SECOND PLURALITY OF METHOD CALLS
310
PERFORM AN IMPACT ANALYSIS FOR THE ONE OR MORE CLIENT WORKFLOWS BASED ON A COMPARISON OF THE FIRST PLURALITY OF DEPENDENCIES, THE SECOND PLURALITY OF DEPENDENCIES, AND THE THIRD PLURALITY OF DEPENDENCIES, WHEREIN THE IMPACT ANALYSIS IDENTIFIES UPSTREAM AND DOWNSTREAM DEPENDENCIES FOR THE ONE OR MORE CLIENT WORKFLOWS USING EACH OF THE FIRST, SECOND, AND THIRD DEPENDENCIES

FIG. 3.

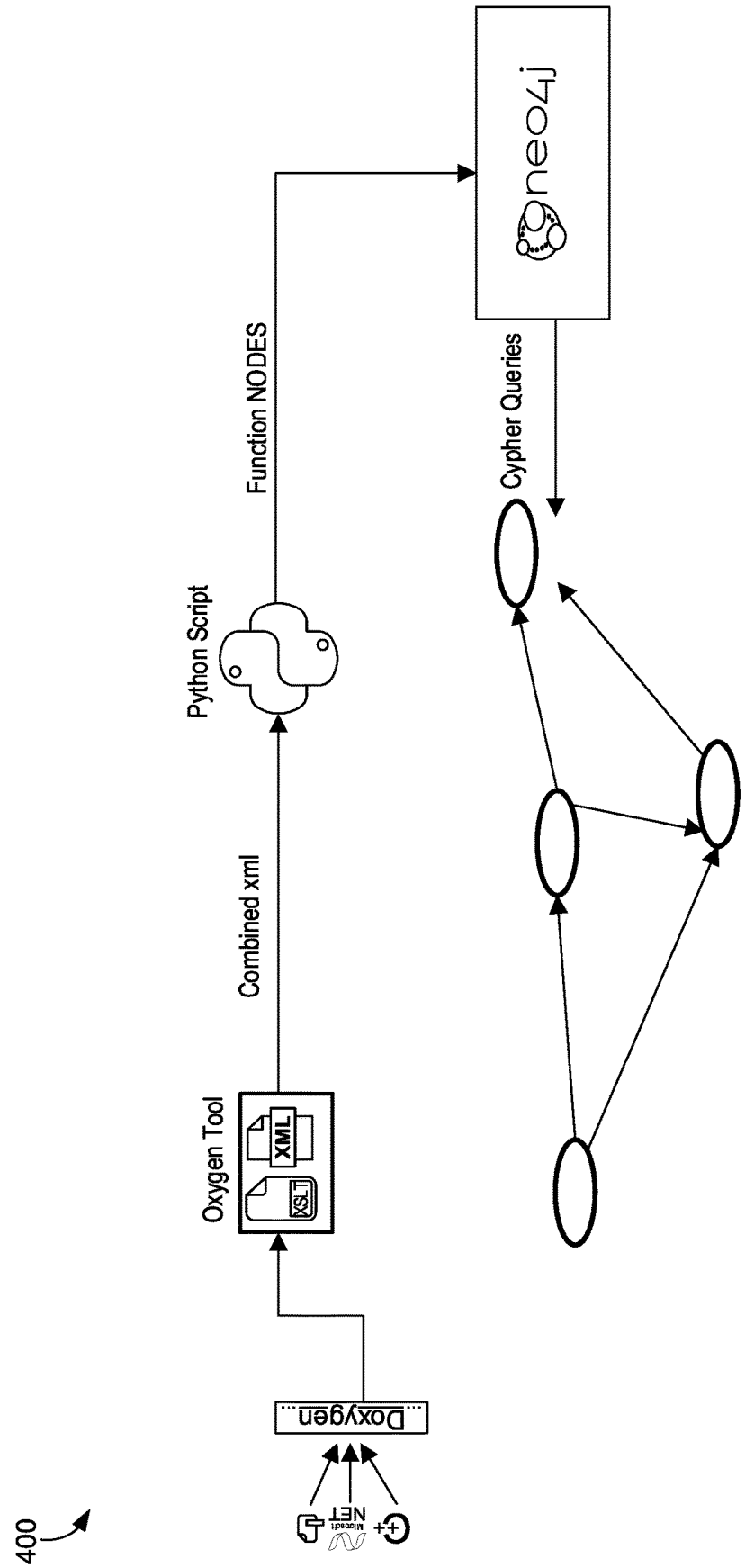

400
C++
.NET
Doxygen
Oxygen Tool
XML
XSLT
Combined xml
Python Script
Function NODES
neo4j
Cypher Queries

FIG. 4.

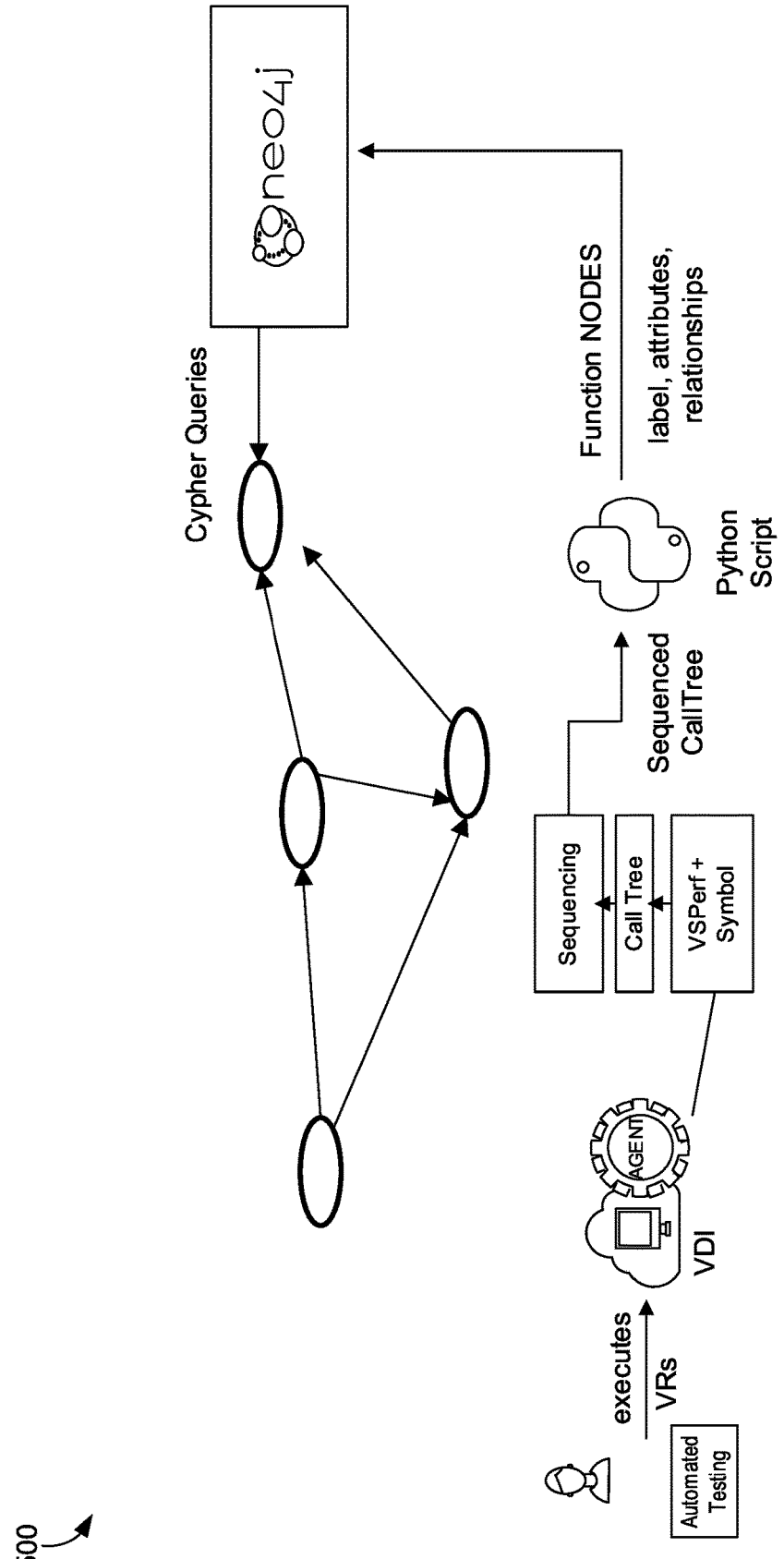

500
Automated Testing
executes
VRs
VDI
AGENT
VSPerf + Symbol
Call Tree
Sequencing
Sequenced CallTree
Python Script
Function NODES
label, attributes, relationships
Cypher Queries
neo4j

FIG. 5.

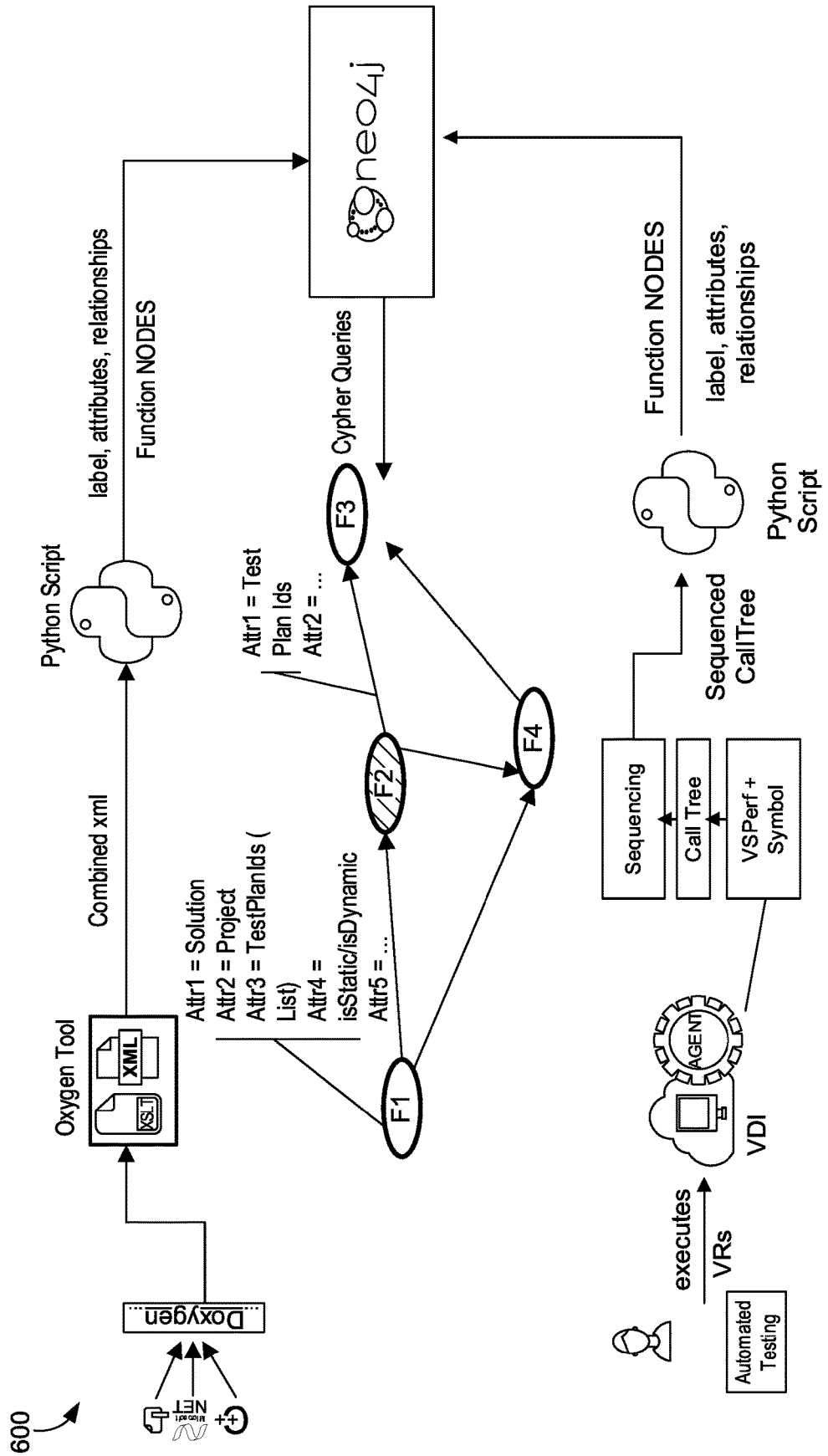

600
Doxygen
Oxygen Tool
XML
XSLT
Combined xml
Python Script
label, attributes, relationships
Function NODES
neo4j
Cypher Queries
F1
F2
F3
F4
Attr1 = Solution
Attr2 = Project
Attr3 = TestPlanIds (List)
Attr4 = isStatic/isDynamic
Attr5 = ...
Attr1 = Test Plan Ids
Attr2 = ...
Function NODES
label, attributes, relationships
Python Script
Sequenced CallTree
Sequencing
Call Tree
VSPerf + Symbol
AGENT
VDI
executes
VRs
Automated Testing

FIG. 6.

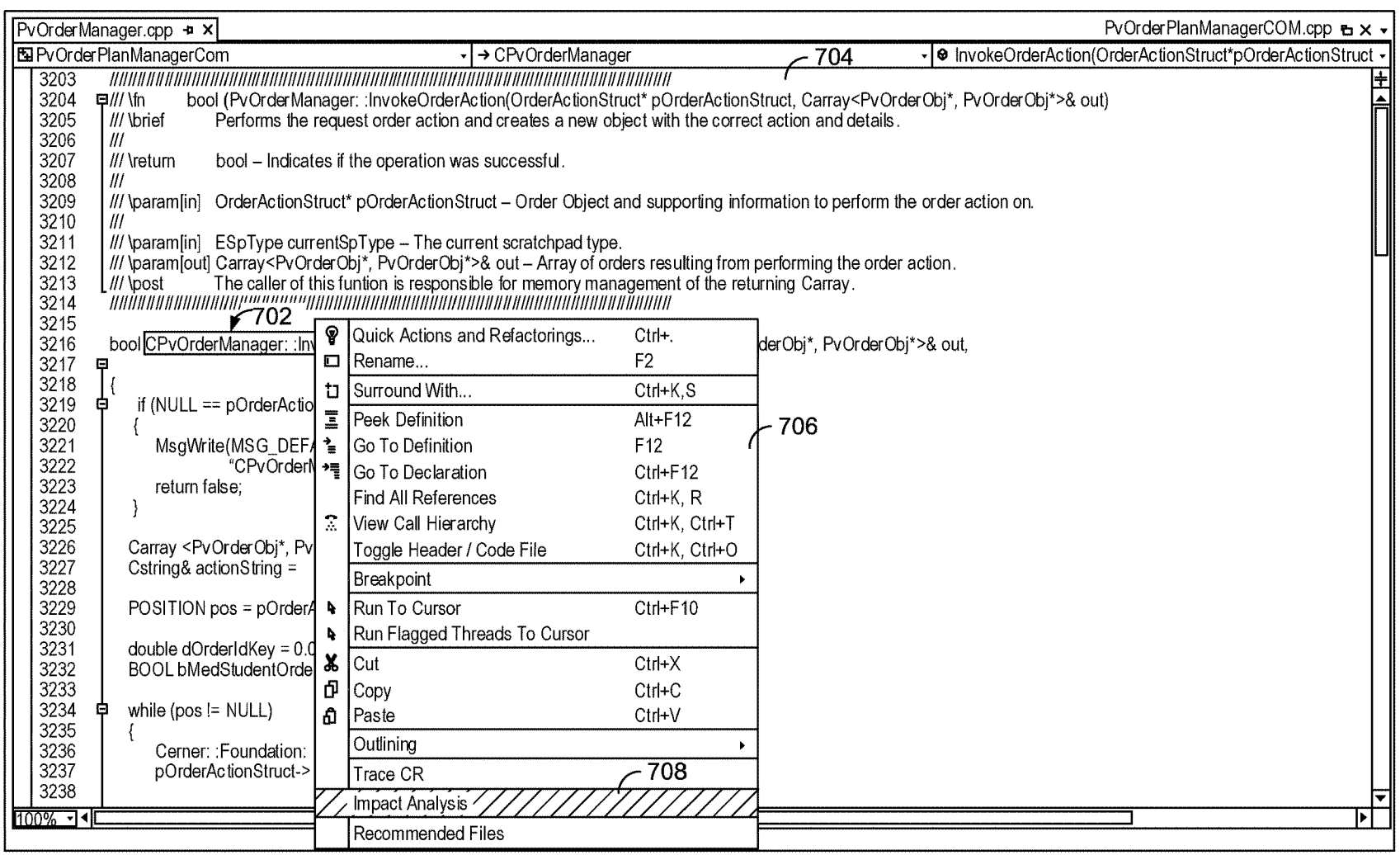

700
PvOrderManager.cpp
PvOrderPlanManagerCOM.cpp
PvOrderPlanManagerCom
CPvOrderManager
704
InvokeOrderAction(OrderActionStruct*pOrderActionStruct
3203 //
3204 /// \fn bool (PvOrderManager: :InvokeOrderAction(OrderActionStruct* pOrderActionStruct, Carray<PvOrderObj*, PvOrderObj*>& out)
3205 /// \brief Performs the request order action and creates a new object with the correct action and details.
3206 ///
3207 /// \return bool – Indicates if the operation was successful.
3208 ///
3209 /// \param[in] OrderActionStruct* pOrderActionStruct – Order Object and supporting information to perform the order action on.
3210 ///
3211 /// \param[in] ESpType currentSpType – The current scratchpad type.
3212 /// \param[out] Carray<PvOrderObj*, PvOrderObj*>& out – Array of orders resulting from performing the order action.
3213 /// \post The caller of this funtion is responsible for memory management of the returning Carray.
3214 //
3215
3216 bool CPvOrderManager: :Inv
3217
3218 {
3219 if (NULL == pOrderActio
3220 {
3221 MsgWrite(MSG_DEF
3222 "CPvOrderM
3223 return false;
3224 }
3225
3226 Carray <PvOrderObj*, Pv
3227 Cstring& actionString =
3228
3229 POSITION pos = pOrderA
3230
3231 double dOrderIdKey = 0.0
3232 BOOL bMedStudentOrde
3233
3234 while (pos != NULL)
3235 {
3236 Cerner: :Foundation:
3237 pOrderActionStruct->
3238
derObj*, PvOrderObj*>& out,
702
Quick Actions and Refactorings... Ctrl+.
Rename... F2
Surround With... Ctrl+K,S
Peek Definition Alt+F12
Go To Definition F12
Go To Declaration Ctrl+F12
Find All References Ctrl+K, R
View Call Hierarchy Ctrl+K, Ctrl+T
Toggle Header / Code File Ctrl+K, Ctrl+O
Breakpoint
Run To Cursor Ctrl+F10
Run Flagged Threads To Cursor
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Outlining
Trace CR
Impact Analysis
Recommended Files
706
708
100%

FIG. 7.

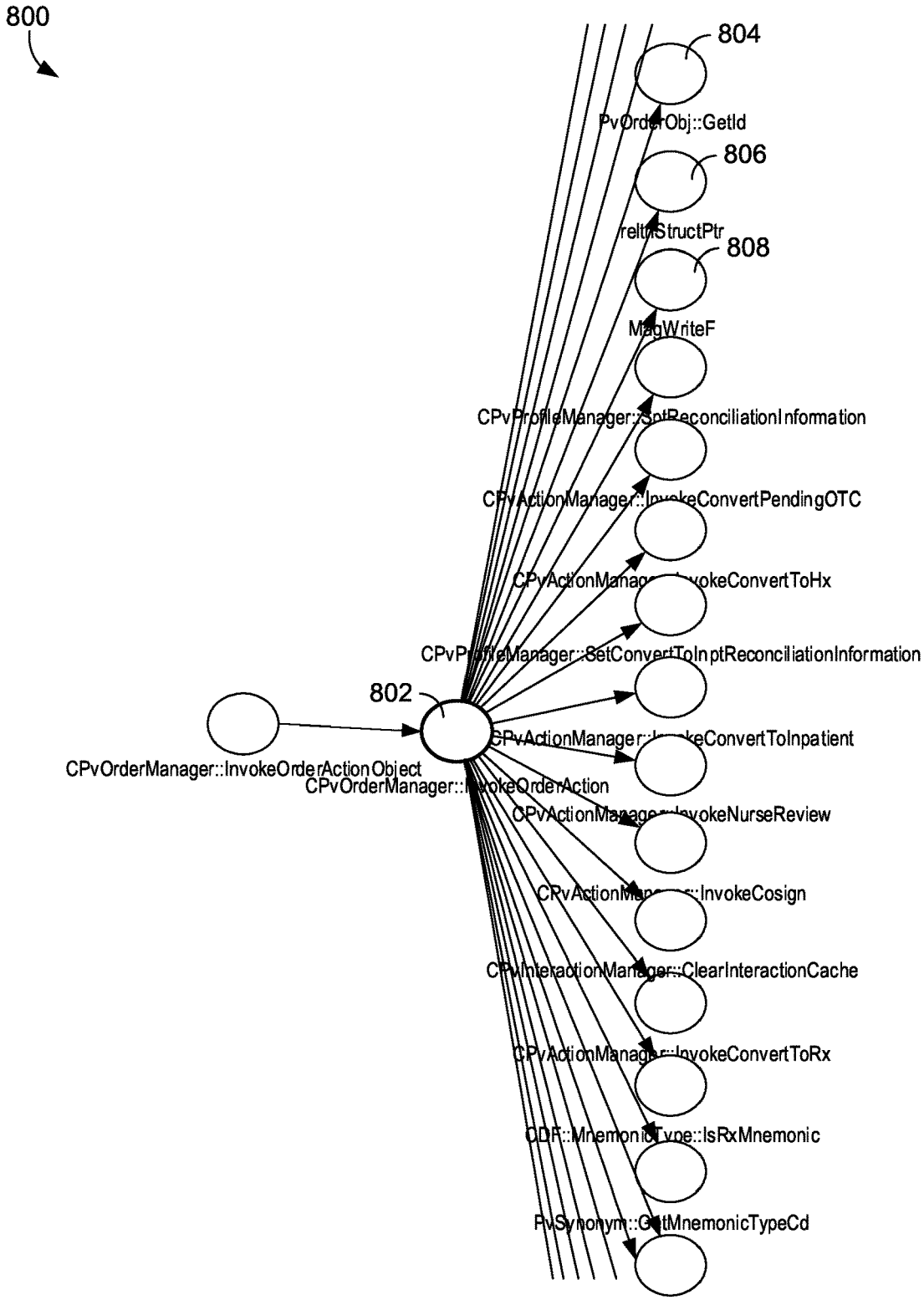

800
804
PvOrderObj::GetId
806
808
MagWriteF
802
CPvOrderManager::InvokeOrderActionObject
CPvOrderManager::InvokeOrderAction
CPvActionManager::InvokeNurseReview
CPvActionManager::InvokeCosign
CPvInteractionManager::ClearInteractionCache
CDF::MnemonicType::IsRxMnemonic

FIG. 8.

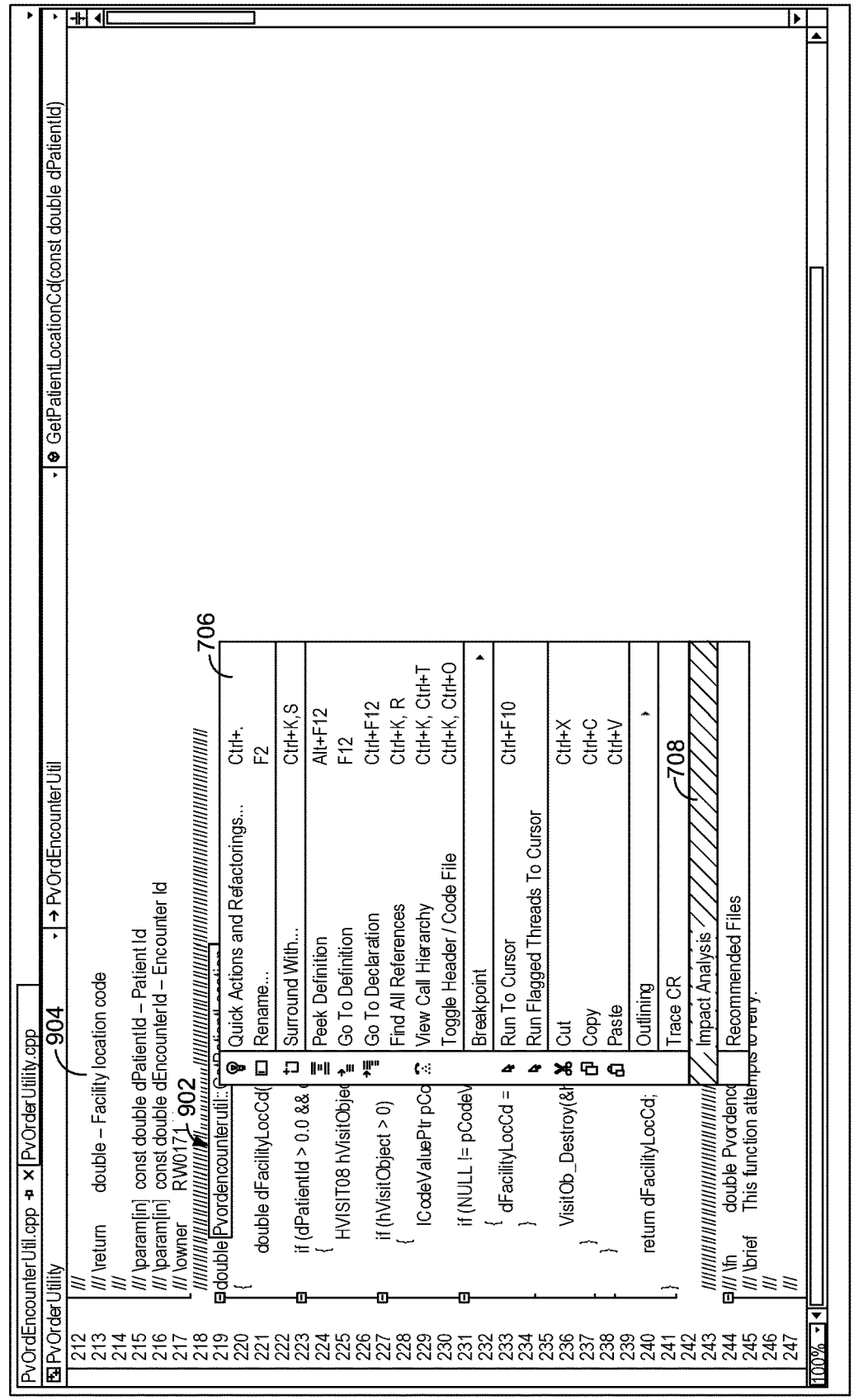

900
PvOrdEncounterUtil.cpp
PvOrderUtility.cpp
PvOrderUtility
PvOrdEncounterUtil
GetPatientLocationCd(const double dPatientId)
904
902
706
708
/// \return double – Facility location code
/// \param[in] const double dPatientId – Patient Id
/// \param[in] const double dEncounterId – Encounter Id
/// \owner RW0171
double Pvordencounterutil::
double dFacilityLocCd(
if (dPatientId > 0.0 &&
HVISIT08 hVisitObje
if (hVisitObject > 0)
ICodeValuePtr pCo
if (NULL != pCodeV
dFacilityLocCd =
VisitOb_Destroy(&h
return dFacilityLocCd;
/// \fn double Pvordenc
/// \brief This function atte
Quick Actions and Refactorings... Ctrl+.
Rename... F2
Surround With... Ctrl+K,S
Peek Definition Alt+F12
Go To Definition F12
Go To Declaration Ctrl+F12
Find All References Ctrl+K, R
View Call Hierarchy Ctrl+K, Ctrl+T
Toggle Header / Code File Ctrl+K, Ctrl+O
Breakpoint
Run To Cursor Ctrl+F10
Run Flagged Threads To Cursor
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Outlining
Trace CR
Impact Analysis
Recommended Files
100%

FIG. 9.

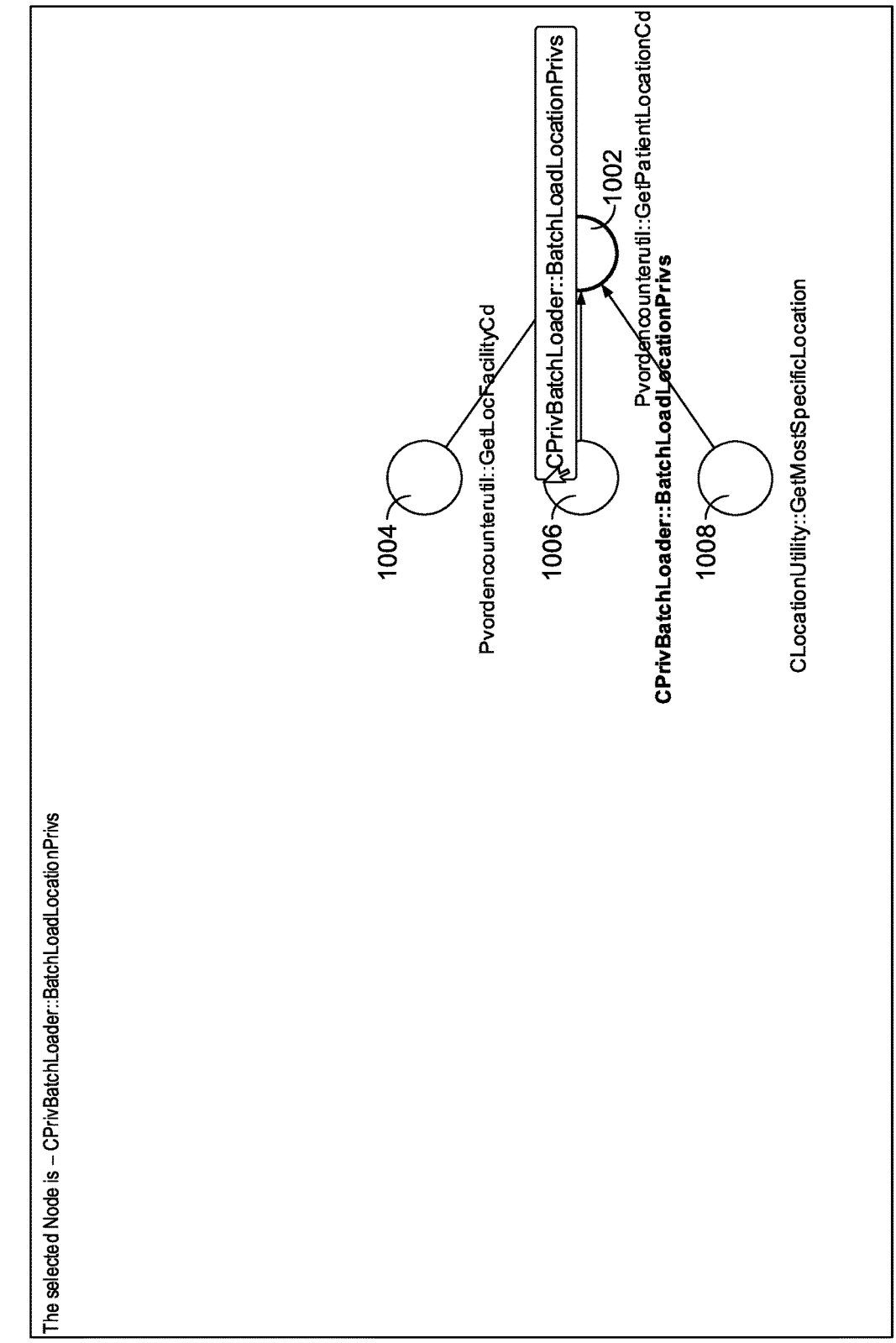

1000
The selected Node is – CPrivBatchLoader::BatchLoadLocationPrivs
1004
Pvordencounterutil::GetLocFacilityCd
CPrivBatchLoader::BatchLoadLocationPrivs
1002
1006
Pvordencounterutil::GetPatientLocationCd
CPrivBatchLoader::BatchLoadLocationPrivs
1008
CLocationUtility::GetMostSpecificLocation

FIG. 10.

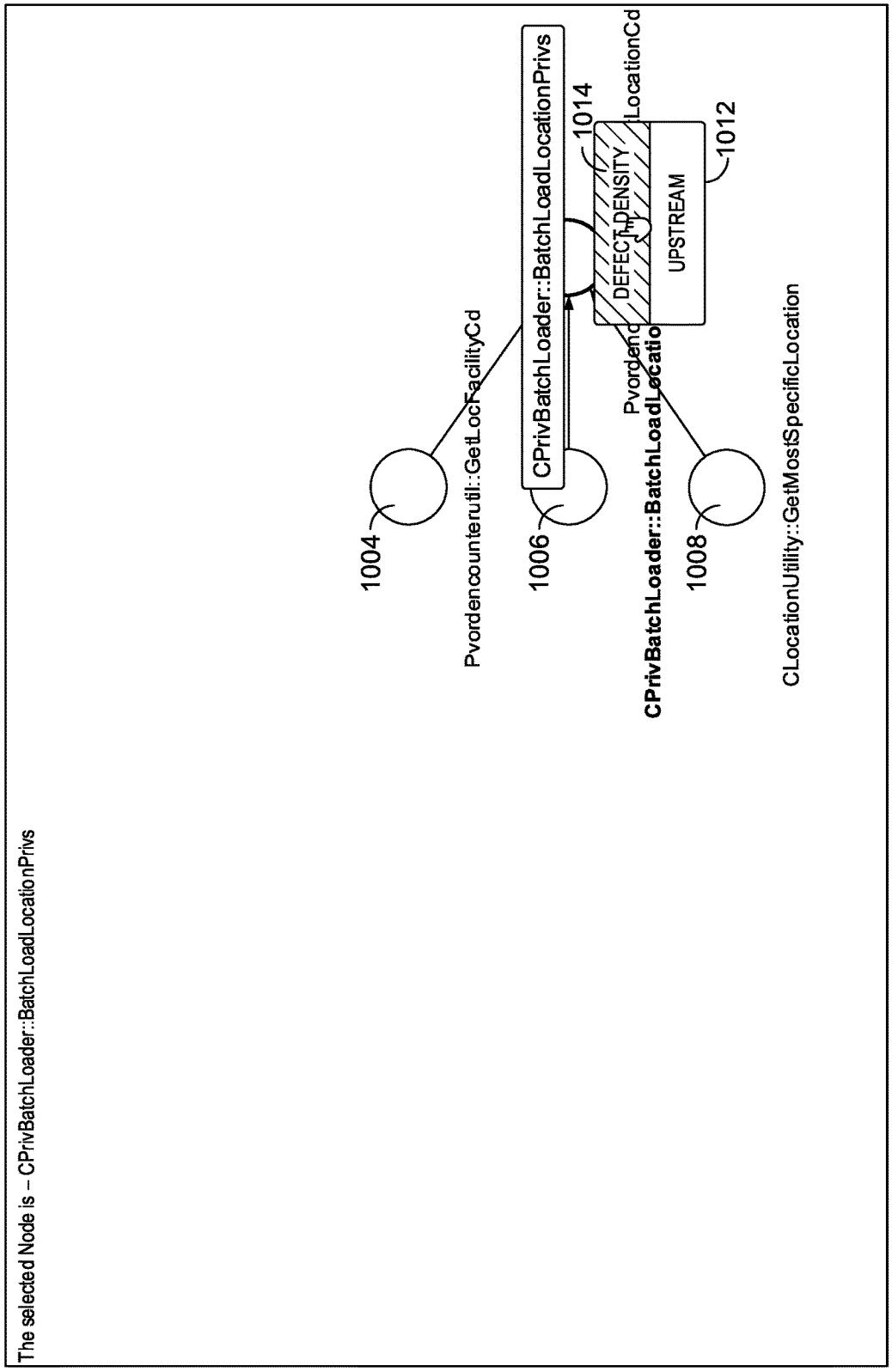

1100
The selected Node is – CPrivBatchLoader::BatchLoadLocationPrivs
1004
Pvordencounterutil::GetLocFacilityCd
1006
CPrivBatchLoader::BatchLoadLocationPrivs
1014
DEFECTDENSITY
LocationCd
1012
UPSTREAM
1008
CPrivBatchLoader::BatchLoadLocatio
CLocationUtility::GetMostSpecificLocation

FIG. 11.

1200

You are trying to modify high defect density method, please make sure existing CRs are not impacted. Following are the impacted CRs.

Success! 36 results

PERFORMANCE: 0 results STABILITY: 0 results

CHIA: 0 results PF: 0 results

CR NUMBER	TYPE	SOLUTION CD	STATUS	CHIA	PF	CLASSIFICATION
BBT-212	Defect	Blood Bank Transfusion	Closed		No	
BBT-253	Defect	Blood Bank Transfusion	Closed		No	
BBT-128	Defect	Blood Bank Transfusion	Closed		No	
BBT-143	Defect	Blood Bank Transfusion	Closed		No	
BBT-983	Enhancement	Blood Bank Transfusion	Closed			
1-319167130	Defect	Blood Bank Transfusion	Closed		No	
1-319074779	Defect	Blood Bank Transfusion	Closed		No	
1-319136950	Defect	Blood Bank Transfusion	Closed		No	
1-319145482	Defect	Blood Bank Transfusion	Closed		No	
1-319244816	Defect	Blood Bank Transfusion	Closed		No	

Previous Page 1 of 4 10 rows Next

DETAILED CRS

FIG. 12.

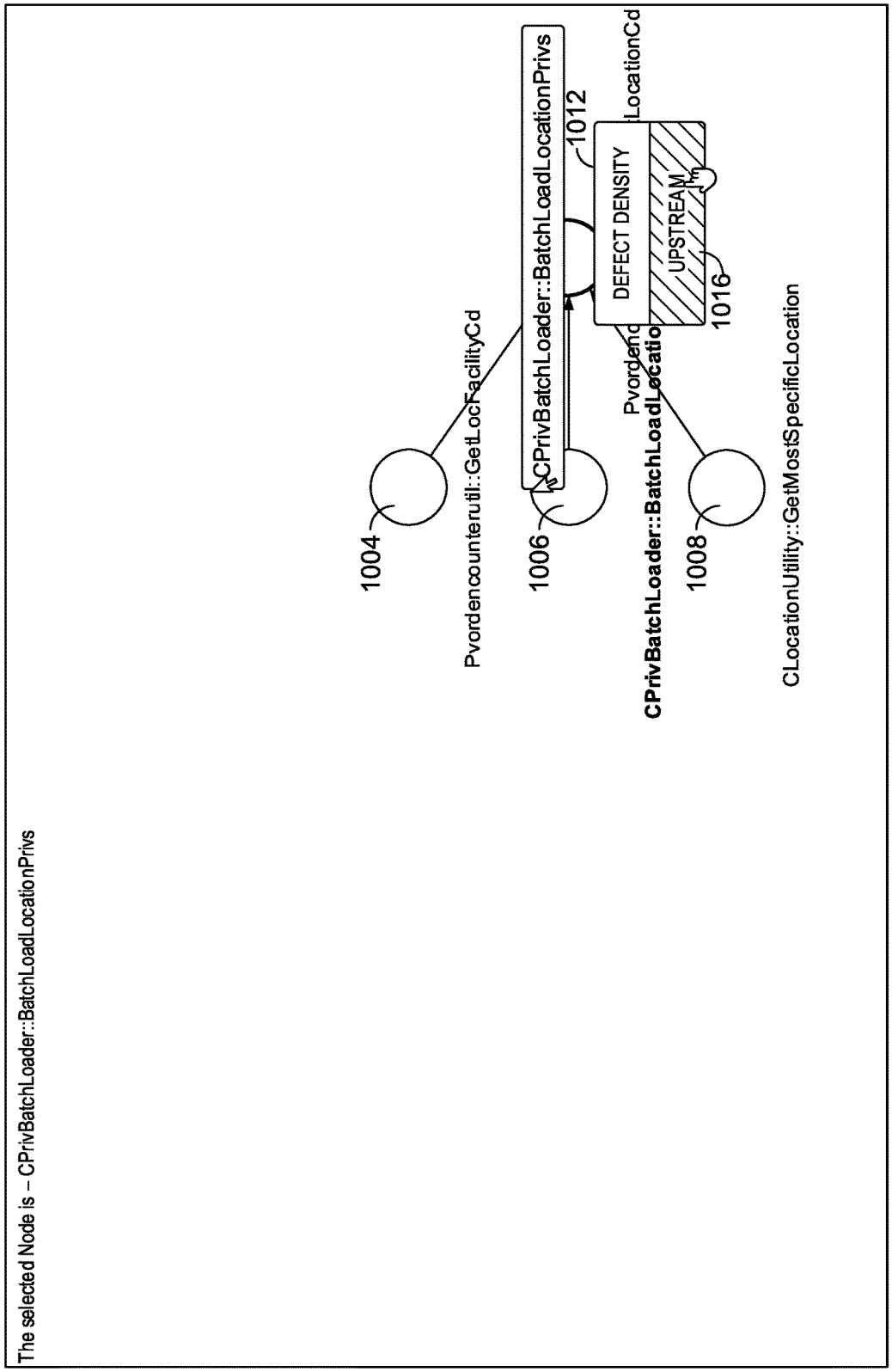

1300
The selected Node is – CPrivBatchLoader::BatchLoadLocationPrivs
1004
Pvordencounterutil::GetLocFacilityCd
1006
CPrivBatchLoader::BatchLoadLocationPrivs
1012
DEFECT DENSITY
UPSTREAM
1016
LocationCd
Pvordend
CPrivBatchLoader::BatchLoadLocatio
1008
CLocationUtility::GetMostSpecificLocation

FIG. 13.

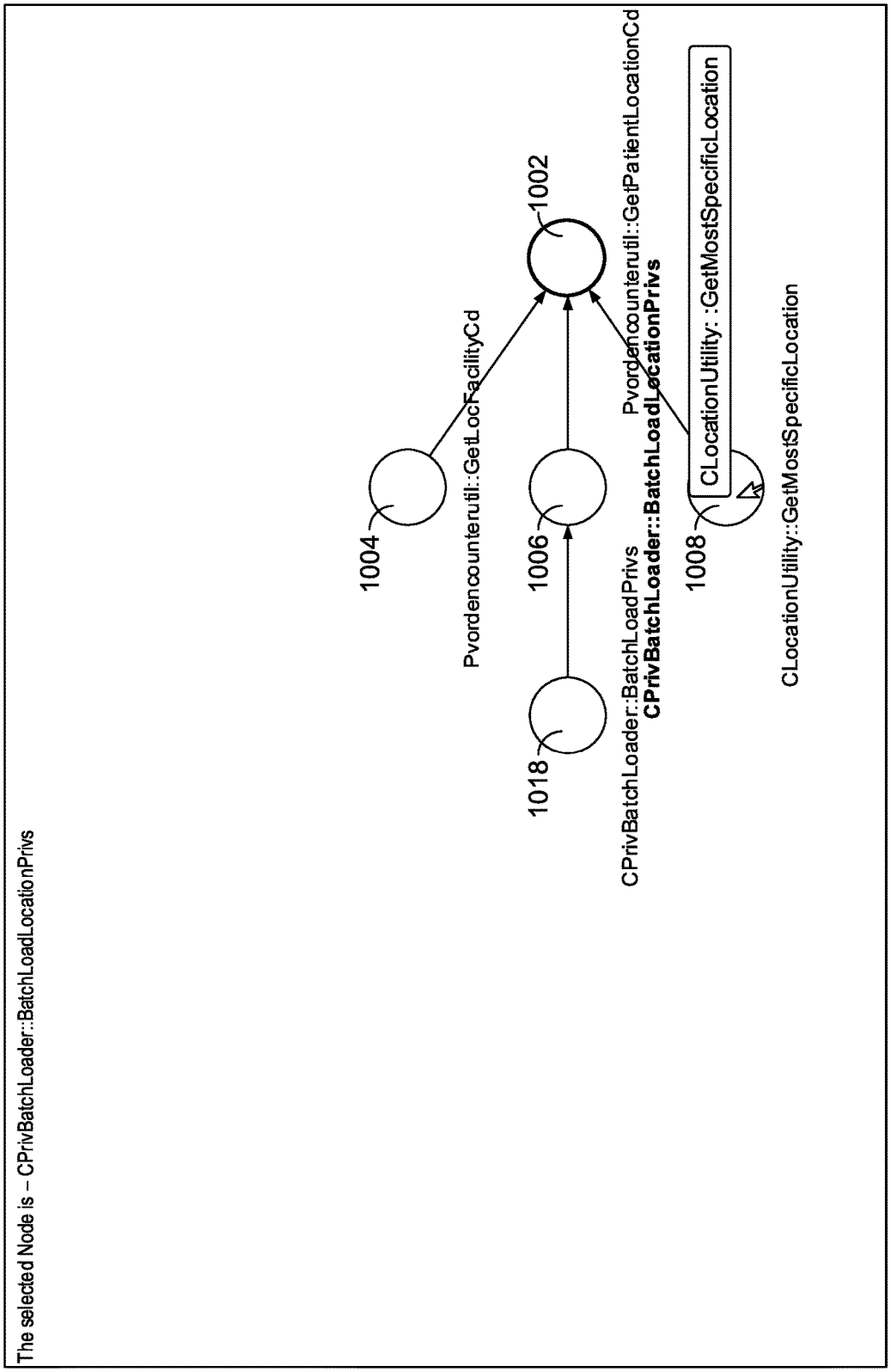

1400
The selected Node is – CPrivBatchLoader::BatchLoadLocationPrivs
1004
Pvordencounterutil::GetLocFacilityCd
1002
1006
CPrivBatchLoader::BatchLoadPrivs
1018
Pvordencounterutil::GetPatientLocationCd
CPrivBatchLoader::BatchLoadLocationPrivs
1008
CLocationUtility: :GetMostSpecificLocation
CLocationUtility::GetMostSpecificLocation

FIG. 14.

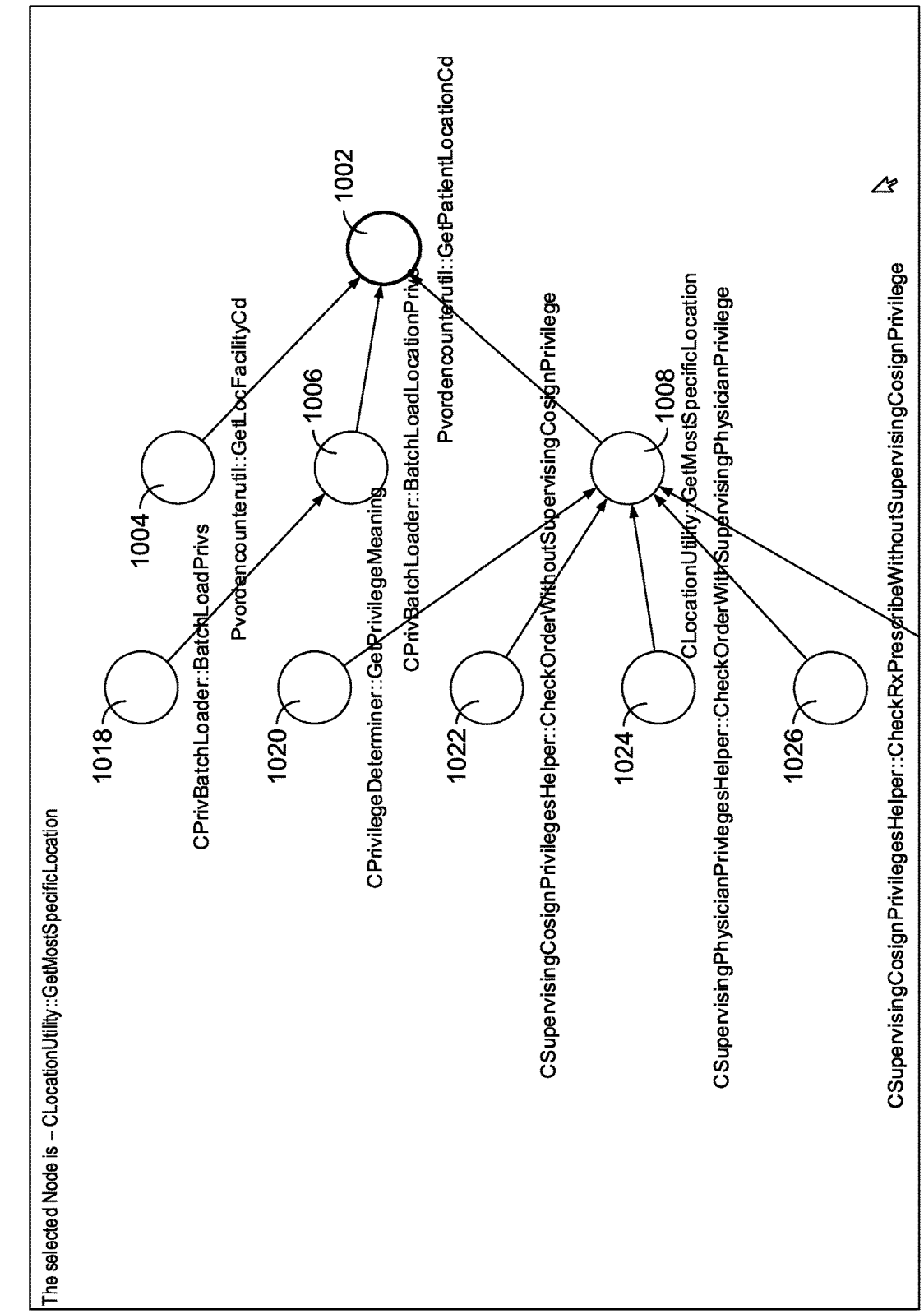

1500
The selected Node is – CLocationUtility::GetMostSpecificLocation
1018
1004
CPrivBatchLoader::BatchLoadPrivs
PvordencounterutilGetLocFacilityCd
1020
1006
CPrivilegeDeterminer::GetPrivilegeMeaning
CPrivBatchLoader::BatchLoadLocationPrivs
1002
PvordencounterutilGetPatientLocationCd
1022
CSupervisingCosignPrivilegesHelper::CheckOrderWithoutSupervisingCosignPrivilege
1024
1008
CLocationUtility::GetMostSpecificLocation
CSupervisingPhysicianPrivilegesHelper::CheckOrderWithSupervisingPhysicianPrivilege
1026
CSupervisingCosignPrivilegesHelper::CheckRxPrescribeWithoutSupervisingCosignPrivilege

FIG. 15.

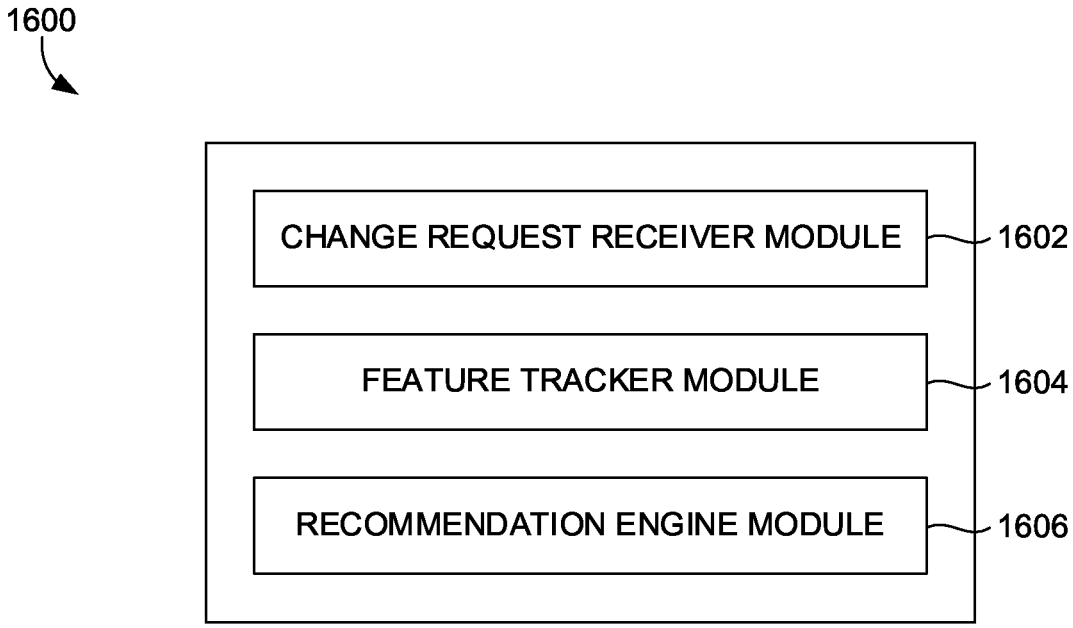

1600
CHANGE REQUEST RECEIVER MODULE
1602
FEATURE TRACKER MODULE
1604
RECOMMENDATION ENGINE MODULE
1606

FIG. 16.

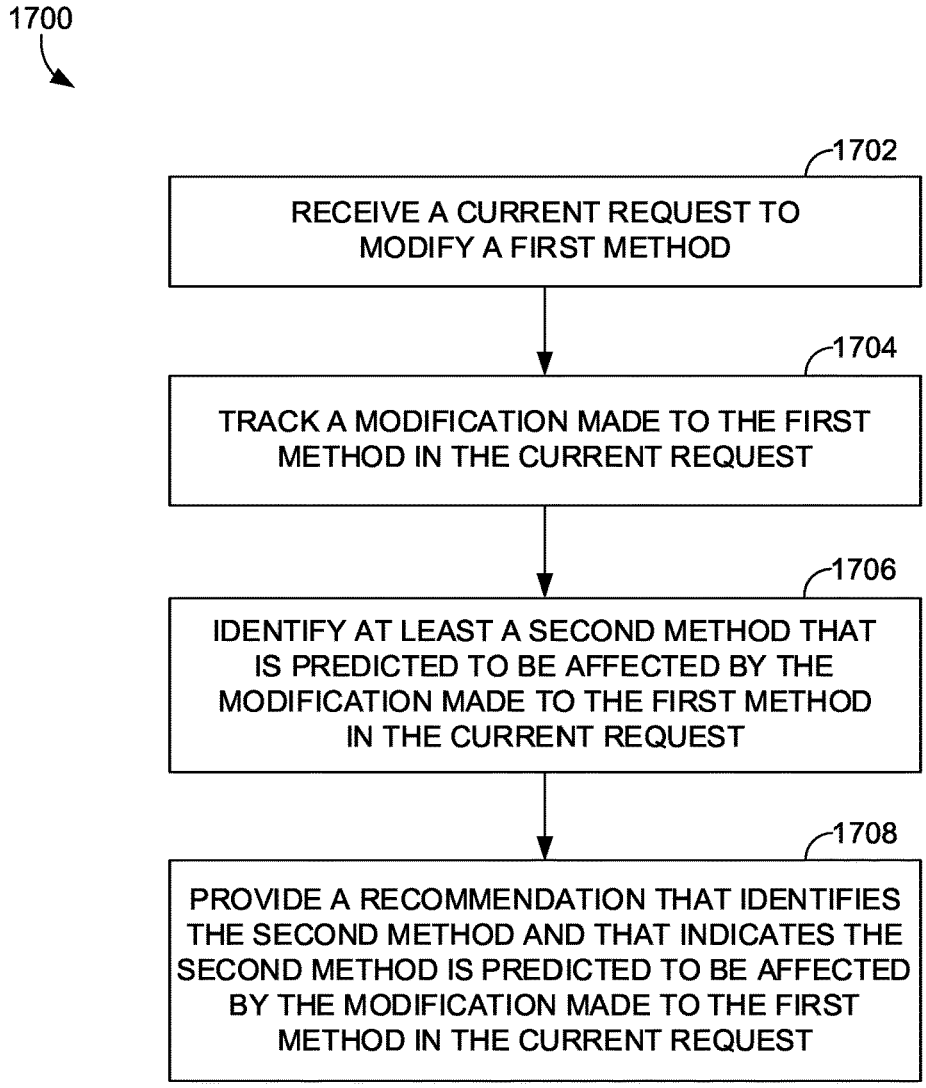

1700
1702
RECEIVE A CURRENT REQUEST TO MODIFY A FIRST METHOD
1704
TRACK A MODIFICATION MADE TO THE FIRST METHOD IN THE CURRENT REQUEST
1706
IDENTIFY AT LEAST A SECOND METHOD THAT IS PREDICTED TO BE AFFECTED BY THE MODIFICATION MADE TO THE FIRST METHOD IN THE CURRENT REQUEST
1708
PROVIDE A RECOMMENDATION THAT IDENTIFIES THE SECOND METHOD AND THAT INDICATES THE SECOND METHOD IS PREDICTED TO BE AFFECTED BY THE MODIFICATION MADE TO THE FIRST METHOD IN THE CURRENT REQUEST

FIG. 17.

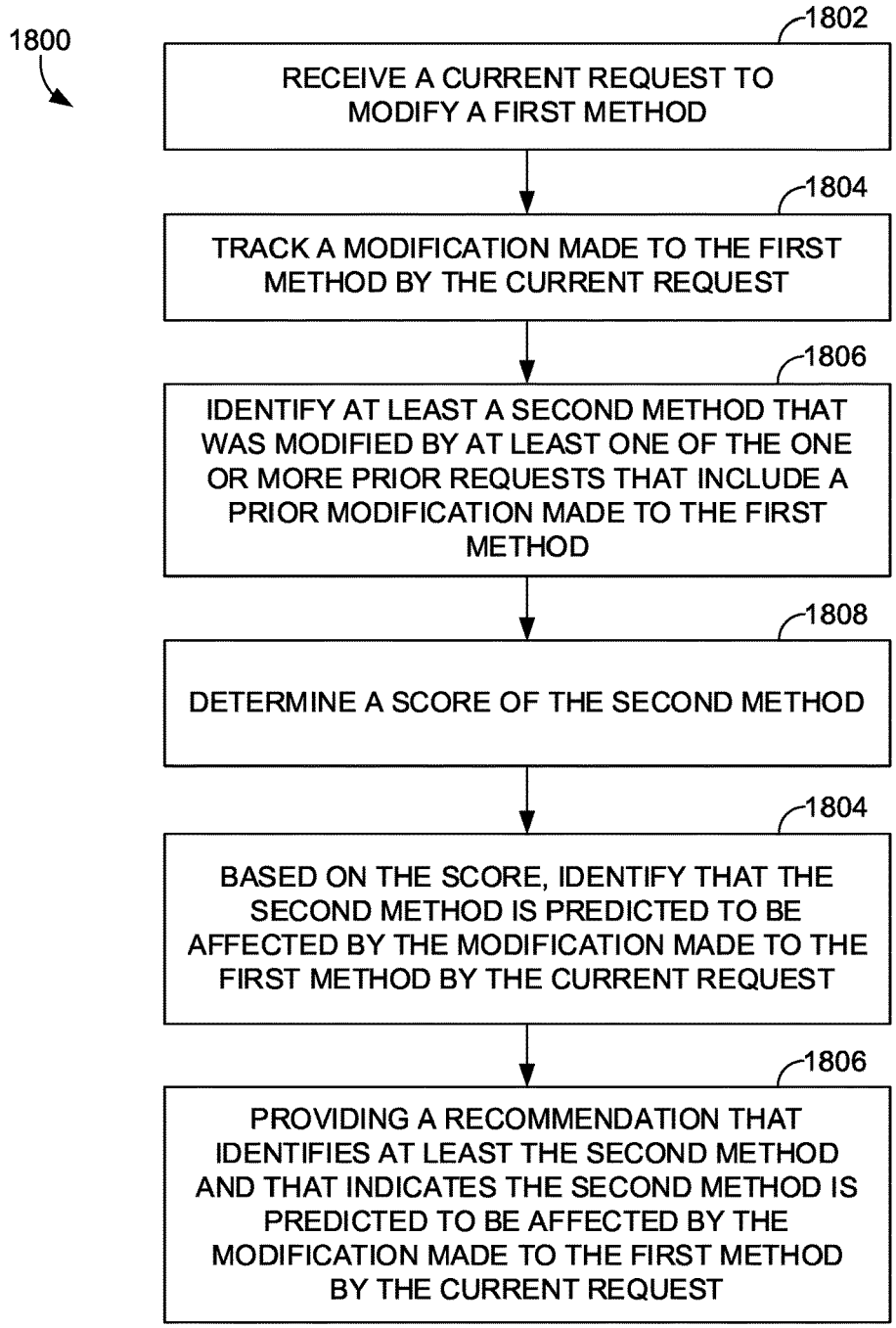

1800
1802
RECEIVE A CURRENT REQUEST TO MODIFY A FIRST METHOD
1804
TRACK A MODIFICATION MADE TO THE FIRST METHOD BY THE CURRENT REQUEST
1806
IDENTIFY AT LEAST A SECOND METHOD THAT WAS MODIFIED BY AT LEAST ONE OF THE ONE OR MORE PRIOR REQUESTS THAT INCLUDE A PRIOR MODIFICATION MADE TO THE FIRST METHOD
1808
DETERMINE A SCORE OF THE SECOND METHOD
1804
BASED ON THE SCORE, IDENTIFY THAT THE SECOND METHOD IS PREDICTED TO BE AFFECTED BY THE MODIFICATION MADE TO THE FIRST METHOD BY THE CURRENT REQUEST
1806
PROVIDING A RECOMMENDATION THAT IDENTIFIES AT LEAST THE SECOND METHOD AND THAT INDICATES THE SECOND METHOD IS PREDICTED TO BE AFFECTED BY THE MODIFICATION MADE TO THE FIRST METHOD BY THE CURRENT REQUEST

FIG. 18.

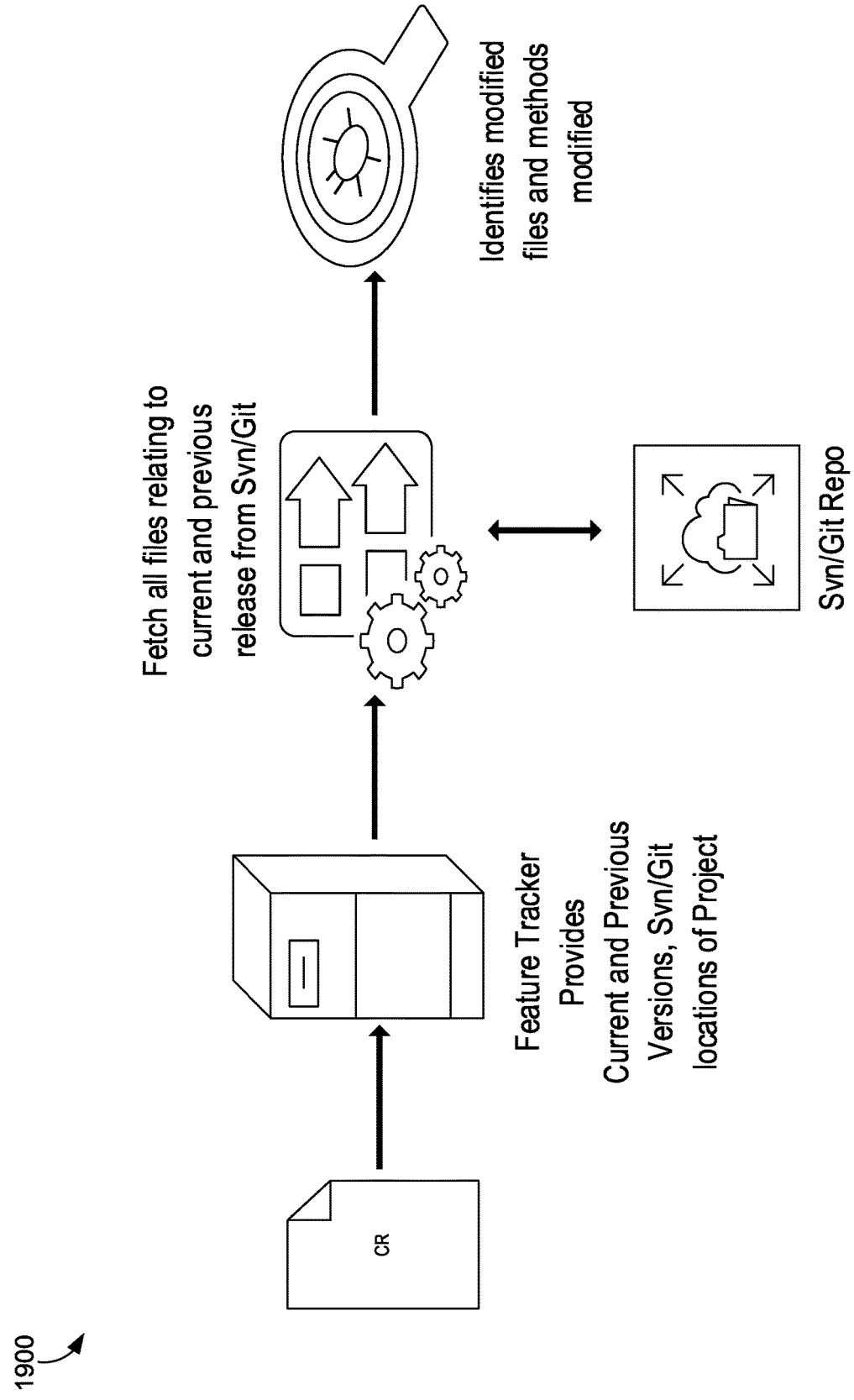

1900
CR
Feature Tracker
Provides
Current and Previous
Versions, Svn/Git
locations of Project
Fetch all files relating to
current and previous
release from Svn/Git
Svn/Git Repo
Identifies modified
files and methods
modified

FIG. 19.

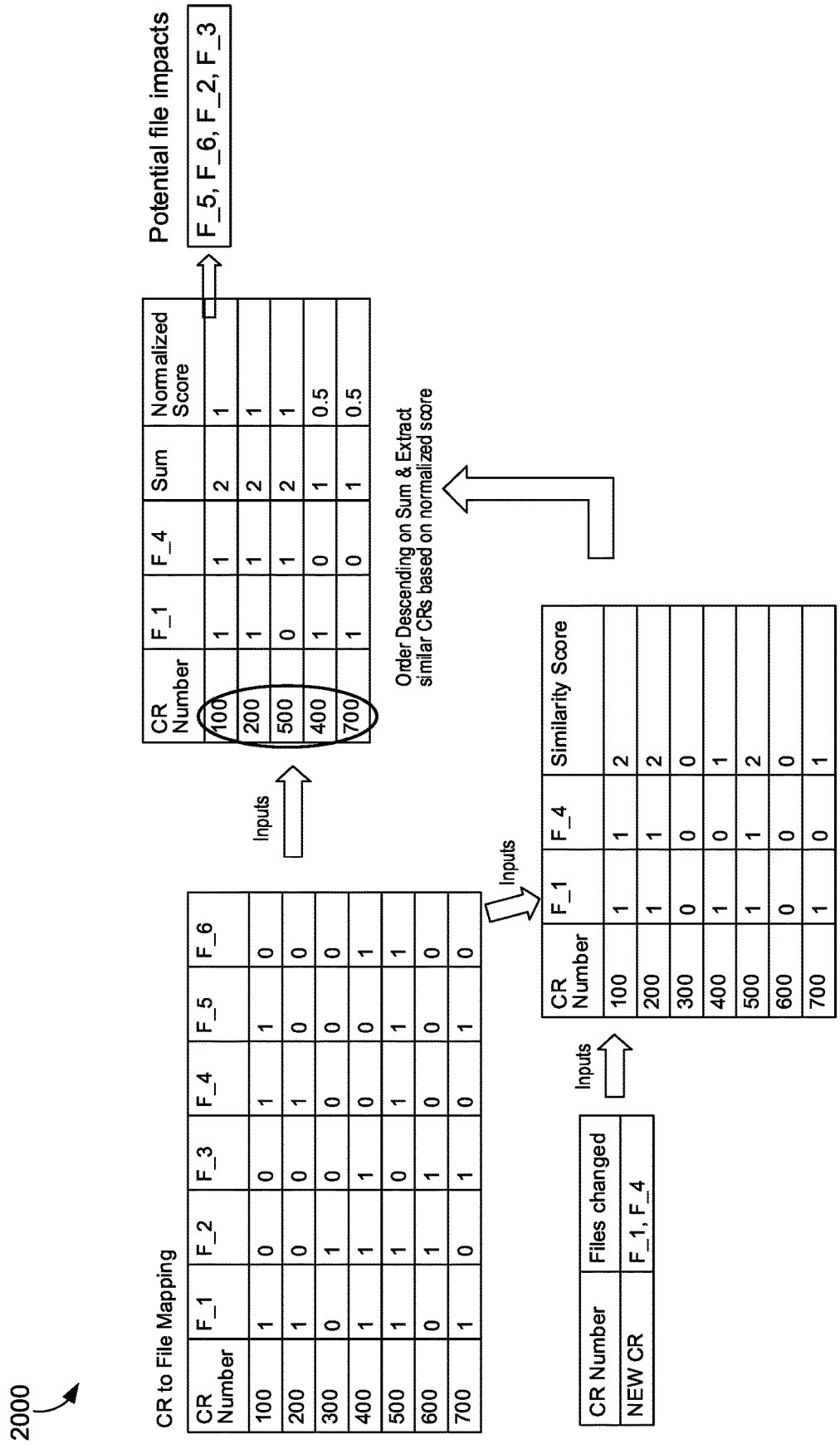

2000
CR to File Mapping
CR Number | F_1 | F_2 | F_3 | F_4 | F_5 | F_6
100 | 1 | 0 | 0 | 1 | 1 | 0
200 | 1 | 0 | 0 | 1 | 0 | 0
300 | 0 | 1 | 0 | 0 | 0 | 0
400 | 1 | 1 | 1 | 0 | 0 | 1
500 | 1 | 1 | 0 | 1 | 1 | 1
600 | 0 | 1 | 1 | 0 | 0 | 0
700 | 1 | 0 | 1 | 0 | 1 | 0
Inputs
CR Number | Files changed
NEW CR | F_1, F_4
Inputs
CR Number | F_1 | F_4 | Similarity Score
100 | 1 | 1 | 2
200 | 1 | 1 | 2
300 | 0 | 0 | 0
400 | 1 | 0 | 1
500 | 1 | 1 | 2
600 | 0 | 0 | 0
700 | 1 | 0 | 1
Inputs
CR Number | F_1 | F_4 | Sum | Normalized Score
100 | 1 | 1 | 2 | 1
200 | 1 | 1 | 2 | 1
500 | 0 | 1 | 2 | 1
400 | 1 | 0 | 1 | 0.5
700 | 1 | 0 | 1 | 0.5
Order Descending on Sum & Extract similar CRs based on normalized score
Potential file impacts
F_5, F_6, F_2, F_3

FIG. 20.

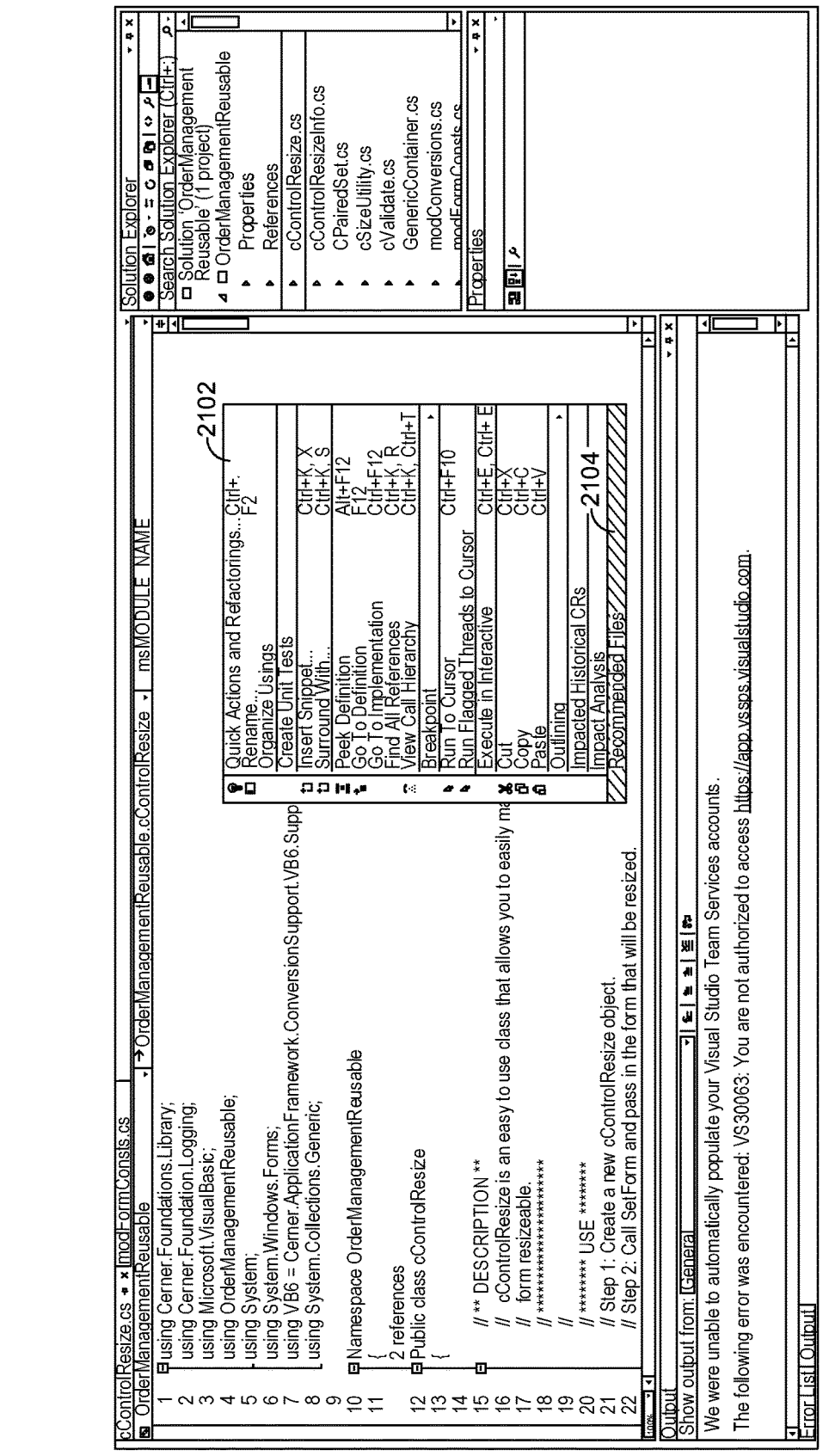

2100
2102
2104
cControlResize.cs
modFormConsts.cs
OrderManagementReusable
OrderManagementReusable.cControlResize
msMODULE_NAME
Solution Explorer
Search Solution Explorer (Ctrl+;)
Solution 'OrderManagement Reusable' (1 project)
OrderManagementReusable
Properties
References
cControlResize.cs
cControlResizeInfo.cs
CPairedSet.cs
cSizeUtility.cs
cValidate.cs
GenericContainer.cs
modConversions.cs
modFormConsts.cs
Properties
Quick Actions and Refactorings... Ctrl+.
Rename... F2
Organize Usings
Create Unit Tests
Insert Snippet... Ctrl+K, X
Surround With... Ctrl+K, S
Peek Definition Alt+F12
Go To Definition F12
Go To Implementation Ctrl+F12
Find All References Ctrl+K, R
View Call Hierarchy Ctrl+K, Ctrl+T
Breakpoint
Run To Cursor Ctrl+F10
Run Flagged Threads to Cursor
Execute in Interactive Ctrl+E, Ctrl+ E
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Outlining
Impacted Historical CRs
Impact Analysis
Recommended Files
using Cerner.Foundations.Library;
using Cerner.Foundation.Logging;
using Microsoft.VisualBasic;
using OrderManagementReusable;
using System;
using System.Windows.Forms;
using VB6 = Cerner.ApplicationFramework.ConversionSupport.VB6.Supp
using System.Collections.Generic;
Namespace OrderManagementReusable
{
2 references
Public class cControlResize
{
// ** DESCRIPTION **
// cControlResize is an easy to use class that allows you to easily ma
// form resizeable.
// **********
//
// ******** USE ********
// Step 1: Create a new cControlResize object.
// Step 2: Call SetForm and pass in the form that will be resized.
Output
Show output from: General
We were unable to automatically populate your Visual Studio Team Services accounts.
The following error was encountered: VS30063: You are not authorized to access https://app.vssps.visualstudio.com.
Error List Output

FIG. 21.

2200
Modified Files Score
File Name
Score
orderprivilegeassistant.cpp
1
privilegedeterminer.cpp
2
pvordutil.cpp
3
supervisingcosignprivlegeshelper.cpp
4
canceldiscontinueorderactionprivilegesdeterminer.cpp
5
completeorderactionprivilegesdeterminer.cpp
6
dcp_providersel.cpp
7
getprivdersel.cpp
8
getprivdefinedtest.cpp
9
Close

FIG. 22.

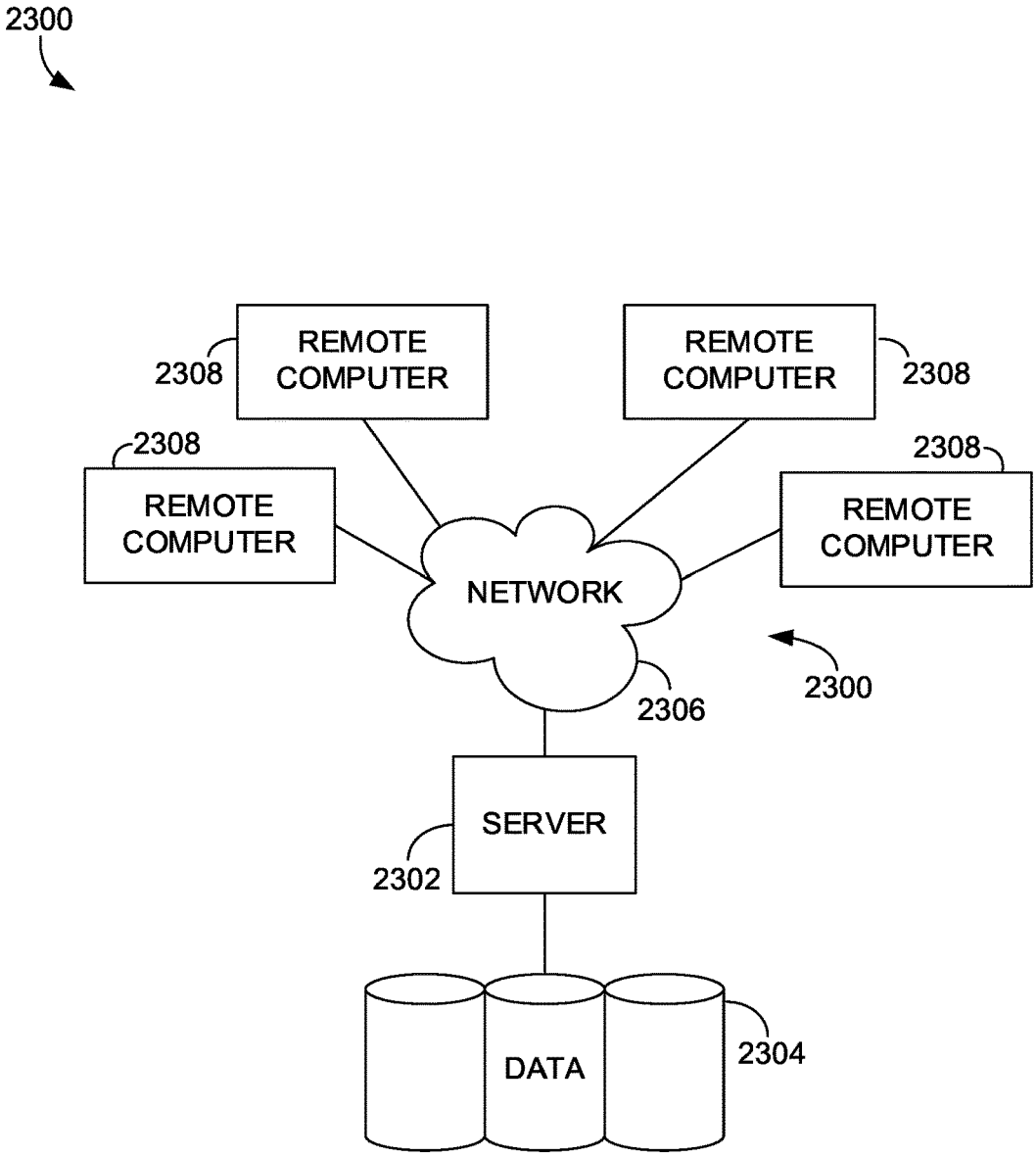

2300
REMOTE COMPUTER
2308
REMOTE COMPUTER
2308
2308
REMOTE COMPUTER
2308
REMOTE COMPUTER
NETWORK
2306
2300
SERVER
2302
DATA
2304

FIG. 23.

SYSTEM AND METHOD FOR PREDICTING THE IMPACT OF SOURCE CODE MODIFICATION BASED ON HISTORICAL SOURCE CODE MODIFICATIONS

CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is related by subject matter to non-provisional U.S. application Ser. No. 17/101,287, co-filed herewith on Nov. 23, 2020 and entitled "SYSTEM AND METHOD FOR IDENTIFYING SOURCE CODE DEFECT INTRODUCTION DURING SOURCE CODE MODIFICATION," which is incorporated herein by reference in its entirety.

BACKGROUND

When a computer software developer attempts to correct a defect and/or to enhance a software or platform functionality, the computer software developer utilizes available tools in an attempt to recognize and understand impacted computer code for the software or platform functionality. However, these attempts made by the computer software developer often create and introduce new errors and defects because the computer software developer lacks complete knowledge and/or visibility of a client's workflow that utilizes the software or platform functionality being modified, updated, or introduced. The available tools also do not provide complete knowledge and/or visibility in this regard. Additionally, these attempts made by the computer software developer can create and introduce further errors and defects because the computer software developer does not have access to tools that facilitates a holistic impact analysis for the client workflows that utilizes the software or platform functionality. Accordingly, the introduced defects and errors interrupt and degrade the client experience for the corresponding workflow that is being impacted by the software or platform functionality being modified, updated, or introduced.

SUMMARY

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The present invention is defined by the claims as supported by the Specification, including the Detailed Description.

In brief and at a high level, this disclosure describes, among other things, methods, systems, and computer-readable media that provide complete and comprehensive knowledge of the complex upstream and downstream dependencies present for the entirety of a client workflow through true knowledge that is obtained by way of multi-pronged dependency graphing, and through intelligent predictions made from prior modifications to the computer code.

In one aspect, a computerized method for impact identification based on code analysis is provided. In some aspects, a static dependency graph is generated that maps a first plurality of dependencies for one or more client workflows encoded in a code base. An internal-domain dynamic dependency graph is also generated, by tracing a first plurality of method calls based on execution of the code base in an internal domain, in aspects. The internal-domain dynamic dependency graph includes, in an aspect, a second plurality of dependencies identified for the one or more client workflows based on the first plurality of method calls. In various aspects, overlap and at least one difference between the first plurality of dependencies and the second plurality of dependencies are identified by superimposing the internal-domain dynamic dependency graph and the static dependency graph. Additionally, a client-domain dynamic dependency graph is generated by tracing a second plurality of method calls based on execution of the code base in a client domain, in one aspect. The client-domain dynamic dependency graph includes, in such an aspect, a third plurality of dependencies identified for the one or more client workflows based on the second plurality of method calls. In some aspects, an impact analysis for the one or more client workflows is performed, based on a comparison of the first plurality of dependencies, the second plurality of dependencies, and the third plurality of dependencies.

In another aspect, one more non-transitory computer-readable media having computer-executable instructions embodied thereon are provided that, when executed using one or more hardware processors, perform a method for impact identification based on code analysis. In some aspects, a static dependency graph is generated that maps a first plurality of dependencies for one or more client workflows encoded in a code base. An internal-domain dynamic dependency graph is generated, in an aspect, by tracing a first plurality of method calls based on execution of the code base in an internal domain. The internal-domain dynamic dependency graph includes a second plurality of dependencies identified for the one or more client workflows based on the first plurality of method calls, in some aspects. In various aspects, overlap and at least one difference between the first plurality of dependencies and the second plurality of dependencies are identified by superimposing the internal-domain dynamic dependency graph and the static dependency graph. A client-domain dynamic dependency graph is generated, in one aspect, by tracing a second plurality of method calls based on execution of the code base in a client domain. The client-domain dynamic dependency graph includes a third plurality of dependencies identified for the one or more client workflows based on the second plurality of method calls, in one aspect. An impact analysis is performed for the one or more client workflows based on a comparison of the first plurality of dependencies, the second plurality of dependencies, and the third plurality of dependencies. In some aspects, the impact analysis identifies specific upstream and downstream method call dependencies for the one or more client workflows using each of the first, second, and third plurality of dependencies. The impact analysis may also, in various aspects, identify overlap and differences between the first, second, and third, dependencies.

A system for impact identification based on code analysis is provided in yet another aspect. In some aspects, the system comprises a dependency graph generating module that generates a static dependency graph that maps a first plurality of dependencies for one or more client workflows encoded in a code base. An internal-domain dynamic dependency graph is generated, in aspects, by the dependency graph generating module which traces a first plurality of method calls based on execution of the code base in an internal domain. In an aspect, the internal-domain dynamic dependency graph includes a second plurality of dependencies identified for the one or more client workflows based on the first plurality of method calls. A client-domain dynamic dependency graph is generated by the dependency graph generating module, which traces a second plurality of

method calls based on execution of the code base in a client domain, in various aspects. The client-domain dynamic dependency graph includes a third plurality of dependencies identified for the one or more client workflows based on the second plurality of method calls. The system includes a superimposing module that identifies overlap and at least one difference between the first plurality of dependencies and the second plurality of dependencies by superimposing the internal-domain dynamic dependency graph and the static dependency graph, in an aspect. The impact analysis module of the system performs an impact analysis for the one or more client workflows based on a comparison of the first plurality of dependencies, the second plurality of dependencies, and the third plurality of dependencies, in various aspects. A graphical user interface module, in some aspects, generates and causes display of the impact analysis, wherein the impact analysis is specific to a first method that is selected from displayed computer code from the code base, and wherein the impact analysis specifies at least one of an upstream dependency relationship or a downstream dependency relationship of a second method relative to the first method.

In one aspect, one more non-transitory computer-readable media having computer-executable instructions embodied thereon are provided, that when executed perform a method to predict additional methods that may be affected by modification to another method based on historical modifications. In such aspects, a current request to modify a first method is received and a modification made to the first method in the current request is tracked. At least a second method is identified that is predicted to be affected by the modification made to the first method in the current request, in some aspects. A recommendation is provided, in one aspect, that identifies the second method and that indicates the second method is predicted to be affected by the modification made to the first method in the current request.

In another aspect, one more non-transitory computer-readable media having computer-executable instructions embodied thereon are provided, that when executed perform a method to predict additional methods that may be affected by modification to another method based on historical modifications. A current request to modify a first method is received and a modification made to the first method by the current request is tracked, in aspects. In some aspects, at least a second method is identified that was modified by at least one of the one or more prior requests that include a prior modification made to the first method. A score for the second method is determined, in as aspect, and based on the score, it can be identified that the second method is predicted to be affected by the modification made to the first method by the current request. In various aspects, a recommendation is provided that identifies at least the second method and that indicates the second method is predicted to be affected by the modification made to the first method by the current request.

In yet another aspect, a system is provided for predicting additional methods that may be affected by modification to another method based on historical modifications. The system includes, in some aspects, a tracking feature module that receives a current request to modify a first method and tracks a modification made to the first method by the current request. In aspects, the system includes a recommendation engine module that identifies at least a second method that was modified by at least one of the one or more prior requests that include a prior modification made to the first method. The recommendation engine module determines a score of the second method, in an aspect. Based on the score, the recommendation engine module identifies that the second method is predicted to be affected by the modification made to the first method by the current request. In some aspects, the recommendation engine module provides a recommendation that identifies at least the second method and that indicates the second method is predicted to be affected by the modification made to the first method by the current request. A graphical user interface module that causes the recommendation to be displayed in a graphical user interface is also included in the system.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects are described in detail below with reference to the attached drawings, wherein:

FIG. **1** is a block diagram of a system for impact identification based on code analysis, in accordance with aspects herein;

FIG. **2** is a flow diagram showing a method for impact identification based on code analysis, in accordance with aspects herein;

FIG. **3** is a flow diagram showing another method for impact identification based on code analysis, in accordance with aspects herein;

FIG. **4** is a simplified graphic diagram depicting static dependency graph generation, in accordance with aspects herein;

FIG. **5** is a simplified graphic diagram depicting dynamic dependency graph generation, in accordance with aspects herein;

FIG. **6** is a simplified graphic diagram depicting superimposition of the static dependency graph of FIG. **4** and the dynamic dependency graph of FIG. **5**, in accordance with aspects herein;

FIG. **7** depicts a graphical user interface of selectable source code and a pop-up menu with an option for performing impact analysis, in accordance with aspects herein;

FIG. **8** depicts a graphical user interface presenting an impact analysis with selectable nodes representing methods and relative dependences, in accordance with aspects herein;

FIG. **9** depicts a graphical user interface of selectable source code and the pop-up menu with the option for performing impact analysis, in accordance with aspects herein;

FIG. **10** depicts a graphical user interface of another impact analysis with selectable nodes representing methods and relative dependences, in accordance with aspects herein;

FIG. **11** depicts the graphical user interface of FIG. **10** with a pop-up menu option for performing a density analysis, in accordance with aspects herein;

FIG. **12** depicts a graphical user interface showing a defect density report, in accordance with aspects herein;

FIG. **13** depicts the graphical user interface of FIG. **10** with a pop-up menu option for performing an upstream impact analysis, in accordance with aspects herein;

FIG. **14** depicts an upstream impact analysis with selectable nodes representing methods and relative dependences, in accordance with aspects herein;

FIG. **15** depicts the upstream impact analysis of FIG. **14** that is updated with additional selectable nodes representing source code and relative dependences based on a node selection, in accordance with aspects herein;

FIG. **16** is a block diagram of a system for impact prediction based on historical code modifications, in accordance with aspects herein;

FIG. **17** depicts a flow diagram showing a method for impact prediction based on historical code modifications, in accordance with aspects herein;

FIG. **18** is a flow diagram showing another method for impact prediction based on historical code modifications, in accordance with aspects herein;

FIG. **19** is a simplified graphic diagram depicting binary value assignment in impact prediction, in accordance with aspects herein;

FIG. **20** depicts binary value assignments for method modifications in prior requests that are used for impact prediction, in accordance with aspects herein;

FIG. **21** depicts a graphical user interface with a pop-menu option for impact prediction, in accordance with aspects herein; and

FIG. **22** depicts a graphical user interface that displays an impact prediction score report, in accordance with aspects herein; and

FIG. **23**. is a diagram of a computing environment, in accordance with aspects herein

DETAILED DESCRIPTION

The subject matter of the present invention is described with specificity herein to meet statutory requirements. However, the Detailed Description itself is not intended to limit the scope of this patent. Rather, the inventors have contemplated that the claimed subject matter might also be embodied in other ways, to include different modules, components, software and hardware features, steps, and/or any combinations thereof, in conjunction with other present or future technologies. Moreover, although the terms "step" and/or "block" may be used herein to connote different elements of methods employed, and the terms should not be interpreted as implying any particular order among or between various steps herein disclosed unless and except when the order of individual steps is explicitly described.

Using the systems, methods, and media described hereinafter, a comprehensive impact analysis can be performed on a computer programming code base (e.g., source code) in order to identify one or more workflows encoded by the code base that are affected when modifications are made to various portions of the code that correspond to various methods. Specifically, complete and highly complex method-to-method upstream and downstream dependencies (i.e., which methods call other particular methods, and which methods are called by other particular methods) of the workflows can be traced and identified directly from the code itself, in an automated manner without any user interaction or manual user input. In this manner, the "impact" the code modification will incur for other methods having dependencies can be identified, summarized, and provided to a user.

Additionally, using the systems, methods, and media described hereinafter, predictions can be made based on an analysis of historical code modifications made to one or more workflows, without performing any dependency tracing. Specifically, aspects herein can predict, in an automated manner without user interaction or manual user input, whether one or more methods, component(s), and/or solution(s) may be affected when specific modifications are made to various portions of the computer programming code base (e.g., source code) for one or more workflows methods. The predictions are determined based on previously-made modifications to the code itself, without performing any dependency tracing. In aspects, when the code for a particular method is to be modified, aspects herein can predict which specific other methods may be affected by the code modifications based on prior code modifications. In this manner, the "impact" the code modification may incur for other methods can be identified, summarized, and provided to a user.

As used herein, a "dependency" can refer to any type of functional call between methods within a component, between one component and another component, and/or between two different solutions, for the workflows within the code base. For simplicity and brevity, "method calls" and "methods" are referred to herein, though it will be understood that functional calls between methods, component(s), and solution(s) are encompassed by and included in the aspects discussed herein. As such, aspects herein are not limited to calls for methods alone, as other functional calls are within the scope of this description. Additionally, the terms "method" and "file" are used interchangeably herein.

Impact Identification

Beginning with FIG. **1**, a block diagram of a system **100** for impact identification is shown in accordance with aspects herein. The system **100** includes a static dependency graph module **102**, a dynamic dependency graph module **104**, a superimposing module **106**, an impact analysis module **108**, and a graphical user interface module **110**, in various aspects. Although not shown in FIG. **1**, the system **100** may include or may access a database that stores one or more code bases, the code bases being computer programming source code for methods, functional calls, components, and solutions of the one or more workflows.

In one aspect, the static dependency graph module **102** generates a static dependency graph that maps a first plurality of dependencies for one or more client workflows, as the workflows are encoded in a code base. The static dependency graph module **102** scans the code in a static manner, without execution of the code, in aspects.

The dynamic dependency graph module **104** may, in aspects, generate a client-domain dynamic dependency graph by tracing a second plurality of method calls based on execution of the code base in a client domain, wherein the client-domain dynamic dependency graph includes a third plurality of dependencies identified for the one or more client workflows based on the second plurality of method calls. Additionally, in some aspects, the dynamic dependency graph module **104** generates an internal-domain dynamic dependency graph by tracing a first plurality of method calls based on execution of the code base in an internal domain, wherein the internal-domain dynamic dependency graph includes a second plurality of dependencies identified for the one or more client workflows based on the first plurality of method calls. The dynamic dependency graph module **104** traces the dependencies that are revealed by running the workflow through the execution of the code, in aspects, whether using an internal domain and/or a client domain to provide a multi-pronged approach to tracing the depend.

In various aspects, the static dependency graph module **102** and the dynamic dependency graph module **104** may be a single integrated module, or may be separate and independent modules within the system **100**.

The system **100** further includes the superimposing module **106**. The superimposing module **106** may identify overlap and at least one difference between the first plurality of dependencies and the second plurality of dependencies. Specifically, the superimposing module **106** superimposes the internal-domain dynamic dependency graph and the static dependency graph, in aspects, in order to make a comparison of the dependencies found by static scanning of

the code and the dependencies found by tracing the workflow when the code is executed in the internal domain. For example, the superimposing module **106** may identify, based on the superimposition of graphs, one or more particular functional calls, methods, components, solutions, and/or dependencies that are shared by both graphs, as well as one or more particular functional calls, methods, components, solutions, and/or dependencies that are different and are not shared by both graphs. The third dependencies found by tracing the workflow when the code is executed in the client domain may also be compared to the superimposed graphs, in aspects.

Accordingly, the impact analysis module **108** may perform an impact analysis for the one or more client workflows based on a comparison of the first plurality of dependencies, the second plurality of dependencies, and the third plurality of dependencies, in some aspects. The impact analysis may identify one or more specific method(s) that have an increased likelihood of being unintentionally affected by modifications made to the code portions that corresponds to other method(s), e.g., defect introduction. The impact analysis provides a comprehensive view of all or nearly all of the dependencies present in the workflows, which have been identified using the multi-pronged approach to mapping and tracing the dependencies in a static and dynamic manner, and using multiple domains (e.g., internal and external). Defect introduction may occur when a modification made to a first method's code affects another upstream or downstream methods in the workflows, wherein the software engineer, client's, or other user's knowledge of the dependency is lacking. The impact analysis creates comprehensive visibility and overcomes this technologically persistent problem.

In the system **100**, the graphical user interface module **110** may generate and cause the display of the impact analysis. The impact analysis may, generally, be specific to a first method that is selected from displayed computer code from the code base, and wherein the impact analysis specifies at least one of an upstream dependency relationship or a downstream dependency relationship of a second method relative to the first method. Accordingly, for each selected portion of code for various methods, an impact analysis may be performed that is specific to the portion of code and the method encoded by the portion of code.

Having described the system **100** and components thereof, it will be understood by those of ordinary skill in the art that system **100** is but one example of a suitable system and is not intended to limit the scope of use or functionality of the present invention. Similarly, system **100** should not be interpreted as imputing any dependency and/or any requirements with regard to each component and combination(s) of components illustrated in FIG. **1**. It will be appreciated by those of ordinary skill in the art that the arrangement and/or integrated placement of components illustrated in FIG. **1** are examples, and other methods, hardware, software, components, and devices for establishing direct, indirect, local, and/or remote communication links between the components may be utilized in implementations of the present invention. It will be understood to those of ordinary skill in the art that the components may be connected in various manners, hardwired or wireless, and may use intermediary components that have been omitted or not included in FIG. **1** for simplicity's sake. Further, it will be understood that the components of the system **100** may communicate with each other directly or, for example, indirectly via a network, including one or more of a telecommunication network, a local area network (LANs), a wide area network (WANs), and/or a peer-to-peer-network, though not shown. Such networking environments may include campus-wide or enterprise-wide computer networks, intranets, and the Internet.

Further, the absence of components from FIG. **1** should not be interpreted as limiting the present invention to exclude additional components and combination(s) of components. Moreover, though components are represented in FIG. **1** as singular components, it will be appreciated that some aspects may include a plurality of devices and/or components such that FIG. **1** should not be considered as limiting the number of any device(s) or component(s) depicted. It should be understood that any number of components shown in FIG. **1** may be employed within the system **100** within the scope of the present invention. Each may be implemented via a single device or multiple devices cooperating in a distributed environment.

Turning to FIGS. **2** and **3**, methods are discussed that can be performed via one or more of the components and component interactions previously described in FIG. **1**. As such, the methods may be discussed with brevity, though it will be understood that the previous discussion and details described therein can be applicable to aspect of the methods of FIGS. **2** and **3**. Additionally or alternatively, it will be understood that the methods discussed herein can be implemented or performed via the execution of computer-readable instructions stored on computer readable media, by way of one or more processors. In one aspect, one or more non-transitory computer-readable storage media having computer-readable instructions or computer-readable program code portions embodied thereon, for execution via one or more processors, can be used to implement and/or perform the methods. For example, computer-readable instructions or computer-readable program code portions can specify the performance of the methods, can specify a sequence of steps of the methods, and/or can identify particular component(s) of a software and/or hardware for performing one or more of the steps of the methods, in aspects. Therefore, in some aspects, the methods can be computer-implemented methods.

FIG. **2** presents a flow diagram showing a method **200** for impact identification based on code analysis, in accordance with aspects herein. In general, one or more code bases that encode one or more client workflows are received, retrieved, obtained, or otherwise accessed as input to the system **100** of FIG. **1**, in various aspects. At block **202**, a static dependency graph is generated that maps a first plurality of dependencies for one or more client workflows encoded in a code base. In some aspects, the static dependency graph module **102** of the system **100** of FIG. **1** generates the static dependency graph that maps the first plurality of dependencies. I

In an aspect, generating the static dependency graph includes scanning computer code that encodes the one or more client workflows in the code base. In one such aspect, all of the first plurality of dependencies between method calls are identified based on scanning the computer code. The static dependency graph includes, in various aspects, a portion or all of the first plurality of dependencies, wherein the first plurality of dependencies represents upstream and downstream calls between methods of the one or more client workflows which are identifiable from a static scan of the code (i.e., no execution/running of the code). The first plurality of dependencies identified may include at least one upstream method that calls another downstream method in the one or more client workflows, and/or the first plurality of dependencies may include at least one downstream method

that is called by another upstream method in the one or more client workflows. In various aspects, upstream and downstream dependencies are identified in the scale of hundreds to millions within the one or more client workflows encoded in the code base.

At block **204**, an internal-domain dynamic dependency graph is generated by tracing a first plurality of method calls based on execution of the code base in an internal domain, wherein the internal-domain dynamic dependency graph includes a second plurality of dependencies identified for the one or more client workflows based on the first plurality of method calls. In some aspects, the dynamic dependency graph module **104** of the system **100** of FIG. **1** generates the internal-domain dynamic dependency graph. In aspects, generating the internal-domain dynamic dependency graph includes executing the one or more client workflows within an internal domain and tracing the first plurality of method calls that occur during the execution of the one or more client workflows. Further, generating the internal-domain dynamic dependency graph may include, in some aspects, identifying at least one of an upstream dependency relationship or a downstream dependency relationship for a portion of or all of the methods that are called from the first plurality of method calls during the code's execution. The internal-domain dynamic dependency graph can include a second plurality of dependencies identified by tracing the first plurality of method calls, and the second plurality of dependencies can include one or more of an upstream dependency relationship and/or a downstream dependency relationship for a portion of or all of the methods from the first plurality of method calls.

At block **206**, overlap and at least one difference between the first plurality of dependencies and the second plurality of dependencies are identified by superimposing the internal-domain dynamic dependency graph and the static dependency graph.

Accordingly, similarities (e.g., overlap) and/or differences between the method dependencies identified from the static graph and the method dependencies identified from the dynamic call graph are identified. For example, one or more of the dependencies identified in the static graph may be missing or absent from the dynamic graph's dependencies, and one or more of the dependencies identified in the dynamic graph may be missing or absent from the static graph's dependencies. For example, at least one method that is present in the internal-domain dynamic dependency graph (e.g., having the second plurality of dependencies) may be identified as being missing or absent from the static dependency graph (e.g., having the first plurality of dependencies), and/or at least one method that is absent or missing in the internal-domain dynamic dependency graph is present from the static dependency graph. Additionally, based on the superimposition of the two graphs, a first set of dependencies that are common to both graphs and/or that are present in both graphs can be identified. In some aspects, the superimposing module **106** of the system **100** of FIG. **1** performs these functions to superimpose graphs and identify similarities and differences. Accordingly, the dependencies found by the static scan of the code base can be compared to the dependencies found by tracing during the execution of the code base in the internal domain, in order to identify similarities and differences in the dependencies that are identified by these two different techniques and the graphs generated.

At block **208**, a client-domain dynamic dependency graph is generated by tracing a second plurality of method calls based on execution of the code base in a client domain, wherein the client-domain dynamic dependency graph includes a third plurality of dependencies identified for the one or more client workflows based on the second plurality of method calls. In some aspects, the dynamic dependency graph module **104** of the system **100** of FIG. **1** generates the client-domain dynamic dependency graph via tracing. Generating the client-domain dynamic dependency graph includes, in some aspects, executing the one or more client workflows within the client domain and tracing the second plurality of method calls during execution of the one or more client workflows in the client domain. Based on tracing the method calls resulting for the code's execution in the client domain, at least one upstream dependency relationship and/or a downstream dependency relationship for methods present in the second plurality of method calls can be identified, in an aspect. Accordingly, the third plurality of dependencies in the client-domain dynamic dependency graph includes the at least one of the upstream dependency relationship or the downstream dependency relationship for the methods present in the second plurality of method calls, in various aspects.

At block **210**, an impact analysis is performed for the one or more client workflows based on a comparison of the first plurality of dependencies, the second plurality of dependencies, and the third plurality of dependencies. In some aspects, the impact analysis module **108** of the system **100** of FIG. **1** generates the impact analysis by performing a comparison of all identified dependencies, and/or by comparing the third plurality of dependencies to the dependency differences (e.g., dependencies that are not shared) identified by the graph superimposition discussed above. Accordingly, the third plurality of dependencies (e.g., client-domain dynamic graph) can be compared to the superimposition of the static dependency graph and the internal-domain dynamic dependency graph in order to identify any method dependencies that are absent or missing from one or both of the static dependency graph and the internal-domain dynamic dependency graph, for example.

In various aspects, the impact analysis identifies specific upstream and/or downstream method call dependencies within the one or more client workflows using each of the first, second, and third dependencies identified from respective graphs, wherein the impact analysis identifies overlap (one or more similarities) between the first, second, and third, dependencies, and wherein the impact analysis identifies one or more differences between the first, second, and third plurality dependencies for the one or more client workflows. In this manner, at least one method and/or method dependent that is present in the superimposed dependency graphs may be identified as being missing or absent from the client-domain dynamic dependency graph, and/or at least one method that is absent or missing in the client-domain dynamic dependency graph is present from the superimposed dependency graphs. Additionally, based on the comparison, a second set of dependencies that are common to and/or that are present in all of the graphs can be identified. These similarities and differences are included in the detailed impact analysis report that can be provided and/or displayed to a user, for example.

In this manner, a comprehensive view of all of the dependency relationships between all of the methods that were identified in all of the one or more client workflows (e.g., upstream, downstream, sequencing) is created by the aspects herein because each of the static, internal-domain dynamic, and client-domain dynamic dependency graphs are generated using a different technique and/or different domain which captures one or more dependencies that might

otherwise have been unknown, missed, omitted, and/or not called depending on the technique or domain employed. The impact analysis results and/or report may be presented through a graphical user interface, as further discussed herein, using the graphical user interface module **110** of the system **100** of FIG. **1**, for example.

FIG. **3** is a flow diagram showing a method **300** for impact identification based on code analysis, in accordance with aspects herein. At block **302**, a static dependency graph is generated that maps a first plurality of dependencies for one or more client workflows encoded in a code base. In some aspects, generating the static dependency graph includes receiving a plurality of code bases as input and generating a plurality of separate dependency maps for the plurality of code bases. In one such aspect, each code base has a separate static dependency map generated such that each code base's dependencies are segregated in different files. The plurality of separate static dependency maps may subsequently be combined or aggregated into a single map that includes all of the dependencies identified for all of the client workflows encoded in the code bases, in some aspects. Further, in one such aspect, the combined map may be parsed. After parsing the combined map, the static dependency graph may be generated, in one aspect, to include and map a first plurality of dependencies. The first plurality of dependencies may include all of the dependencies identified in the plurality of code bases based on static scanning and parsing of the code bases. In some aspects, the static dependency graph module **102** of FIG. **1** may generate the static dependency graph by mapping a first plurality of dependencies for one or more client workflows encoded in a code base.

For example, FIG. **4** provides a simplified graphic diagram **400** depicting dependency graph generation, in accordance with aspects herein. In accordance with FIG. **4**, multiple code bases are received as input. Then, a plurality of separate dependency maps are generated for the plurality of code bases, in one example, by an automated code base documentation generator tool (e.g., shown as Doxygen). The plurality of dependency maps can be combined into one aggregated map by an automated multi-platform editor tool (e.g., shown as Oxygen), in the example of FIG. **4**. Further, an executable script (e.g., written in Python) may be used to parse the aggregated map to reveal one or more functional calls and to identify dependencies, in the example. Based on parsing the combined/aggregated map, dependencies can be identified and input to a graph database management system (e.g., neo4j), in the example of FIG. **4**. Further, queries written in a declarative graph query language (e.g., Cypher queries) may be utilized so that the graph database management system automatically builds and generates the static dependency graph an output. Accordingly, this is just one example for generating a static dependency graph through a static scanning of a code base encoding one or more workflows.

At block **304**, an internal-domain dynamic dependency graph is generated by tracing a first plurality of method calls based on execution of the code base in an internal domain, wherein the internal-domain dynamic dependency graph includes a second plurality of dependencies identified for the one or more client workflows based on the first plurality of method calls. For example, by executing the one or more client workflows within the internal domain, a portion or all of the first plurality of method calls can be traced. As such, the internal-domain dynamic dependency graph can indicate which method calls "called" other particular methods, which specific methods were called by other methods, and the sequencing of calls/calling between methods. In such aspects, a sequenced method call tree that represents a portion of all of the first plurality of method calls traced during the execution of the one or more client workflows in the internal domain can be generated. Using the sequenced method call tree, at least one of an upstream dependency relationship and/or a downstream dependency relationship for a portion or all of the methods resulting from the first plurality of method calls can be identified and included in the internal-domain dynamic dependency graph, in aspects. For example, the internal-domain dynamic dependency graph can include the second plurality of dependencies, wherein the second plurality of dependencies include the at least one of the upstream dependency relationship and/or the downstream dependency relationship for the portion or all of the methods traced using the first plurality of method calls resulting from the execution of the one or more client workflows in the internal domain. In various aspects, the dynamic dependency graph module **104** of FIG. **1** may generate the internal-domain dynamic dependency graph by tracing the first plurality of method calls based on execution of the code base in an internal domain, and/or further functions discussed above.

For example, FIG. **5** depicts a simplified graphic diagram **500** depicting dynamic dependency graph generation, in accordance with aspects herein. In the example of FIG. **5**. In accordance with FIG. **5**, one or more code bases are executed using a processor so that one or more client workflows encoded in one or more code bases are performed or run within, for example, an automated runtime environment that mimics performance and utilization of the client workflow(s). For example, one or more client workflows encoded by the code base are run within an internal domain by executing the code. Based on running the client workflows, a portion of or all of a first plurality of functional calls/method calls performed during execution of the client workflows in the internal domain are traced, for example, as shown in FIG. **5**, by using a Virtual Desktop Infrastructure (VDI) and a script (e.g., shown as "AGENT"). Based on tracing the functional calls/method calls that were performed in the client workflows in the internal domain, a sequenced method call tree that represents a portion or all of the first plurality of method calls traced is generated, as shown in the example of FIG. **5**. Based on the sequenced method call tree, at least one of an upstream dependency relationship and/or a downstream dependency relationship for a portion or all of the methods present in the first plurality of method calls can be identified using automated scripts (e.g., shown as Python language scripts) that feed a graph database management system (e.g., neo4j). Further, queries written in a declarative graph query language (e.g., Cypher queries) may be utilized so that the graph database management system automatically builds and generates the internal-domain dynamic dependency graph an output. Accordingly, this is just one example for generating a dynamic dependency graph through the execution, within an internal domain, of a workflow encoded in a code base.

Continuing, at block **306**, overlap and at least one difference between the first plurality of dependencies and the second plurality of dependencies are identified by superimposing the internal-domain dynamic dependency graph and the static dependency graph. As previously described herein, identifying one or more similarities and/or differences between the first plurality of dependencies and the second plurality of dependencies can include, using the superimposition of the graphs, identification of a first plurality of methods that are present in the internal-domain dynamic dependency graph but which are absent from the static

dependency graph, for example. Additionally, identifying one or more similarities and/or differences between the first plurality of dependencies and the second plurality of dependencies can include, using the superimposition of the graphs, identifying a second plurality of methods that are absent in the internal-domain dynamic dependency graph but which are present in the static dependency graph, for example.

A portion of the first and second plurality of dependencies may be common or shared between both graphs, in some aspects. For example, FIG. **6** is a simplified graphic diagram **600** depicting superimposition of the static dependency graph of FIG. **4** and the internal-domain dynamic dependency graph of FIG. **5**. As shown by the superimposition of FIG. **6**, the method F2 can be identified as being present in the internal-domain dependency graph but is omitted, missing, and/or absent (i.e., is not present) from the static dependency graph, where the method F2 is called by the method F1 (e.g., upstream dependency), and where the method F2 calls the method F3 (e.g., downstream dependency). This process of determining which methods and dependencies are shared or omitted is performed for all of the first and second dependencies included in the superimposition. In some aspects, the superimposing module **106** of FIG. **1** superimposes the internal-domain dynamic dependency graph and the static dependency graph, and identifies the similarities and differences between the first plurality of dependencies and the second plurality of dependencies.

At block **308**, a client-domain dynamic dependency graph is generated by tracing a second plurality of method calls based on execution of the code base in a client domain, wherein the client-domain dynamic dependency graph includes a third plurality of dependencies identified for the one or more client workflows based on the second plurality of method calls. The dynamic dependency graph module **104** of FIG. **1** may create the client-domain dynamic dependent module, in some aspects.

At block **310**, an impact analysis is performed for the one or more client workflows based on a comparison of the first plurality of dependencies, the second plurality of dependencies, and the third plurality of dependencies. The impact analysis identifies specific upstream and downstream method call dependencies for the one or more client workflows using each of the first, second, and third dependencies, in aspects. As such, the impact analysis identifies overlap between the first, second, and third, dependencies, and the impact analysis identifies differences between the first, second, and third dependencies for the one or more client workflows, in some aspects. In various aspects, the impact analysis module **108** of FIG. **1** may perform the impact analysis, generate an impact analysis report, and may provide the impact analysis to another component to cause display of the impact analysis and results. In some aspects, the impact analysis module **108** compares the third plurality of dependencies to one or more of the dependencies that were identified as not being shared by both the static and internal-domain dynamic graphs, as superimposed. The impact analysis may results in a report that individually identifies, for any particular or selected method, all of the upstream and downstream dependencies of that particular methods as aggregated from the first, second, and third dependencies identified. In this manner, a comprehensive view of all of the dependency relationships for every individual method (e.g., upstream, downstream, sequencing) in the workflows is generated because each of the static, internal-domain dynamic, and client-domain dynamic dependency graphs are generated using a different technique and/or different domain which captures one or more dependencies that might otherwise have been unknown, missed, omitted, and/or not called depending on the technique or domain employed.

In further aspects, the method **300** may include generating and causing display of a user-interactive graphical user interface (GUI) that displays computer code for the one or more client workflows encoded in the code base. For example, as shown in FIG. **7**, a graphical user interface **700** displays computer code for the one or more client workflows encoded in the code base. In one aspect, a selection of a first method directly from the computer code displayed in the user-interactive graphical user interface is received, for example, based on an indication of a user selection. In response, an impact analysis report may be automatically performed, or a pop-up menu with a selectable option to perform an impact analysis on the selected method may be displayed in the graphical user interface. As shown in the graphical user interface **700** of FIG. **7**, when a portion **702** of the computer code that encodes the method "CPvOrderManager" is selected in the computer code **704** displayed, a pop-up menu **706** is displayed in response. The pop-up menu **706** includes an impact analysis menu option **708** that can be selected to trigger the display of the impact analysis report for the selected method. In another example, shown in the graphical user interface **900** of FIG. **9**, another portion **902** of computer code **904** displayed in the graphical user interface **900** can be selected, the pop-up menu **706** can be displayed with the impact analysis menu option **708**, and selection trigger the display of the impact analysis report for the selected method. In some aspects, the graphical user interface module **110** of FIG. **1** may generate and cause presentation of one or more of the user-interactive graphical user interfaces described herein, including pop-up menus, menu options, computer code, selectable nodes, and the like for both impact analysis and impact prediction aspects.

In further aspects, and in response to the selection of the method in the code and/or a selectable option in a menu for a selected method, an impact analysis report that is specific to the selected method is displayed in a graphical user interface. In such an aspect, the impact analysis report that is specific to the selected first method specifies at least one of an upstream dependency relationship or a downstream dependency relationship of a second method relative to the selected first method, which are known based on the impact analysis, as previously discussed.

For example, in response to the selection of the impact analysis menu option **708** from FIG. **7**, the graphical user interface **800** of FIG. **8** is generated and caused to be displayed. FIG. **8** depicts the outcomes of the impact analysis (e.g., report) as a graphic representation having a plurality of selectable nodes. Each of the selectable nodes represents a different method and the selectable nodes are arranged to represent the dependencies that are identified for the method that was selected, for example. In FIG. **8**, a first selectable node **802** is presented to represent the method "CPvOrderManager" that was selected in FIG. **7**. A plurality of selectable nodes **804**, **806**, and **808** are also display in FIG. **8** to represent various upstream and downstream method dependencies relative to the method "CPvOrderManager," based on the selection from FIG. **7**. The first selectable node **802**, the plurality of selectable nodes **804**, **806**, and **808**, and their arrangement in the graphical user interface **800** relative to one another, represents the dependencies identified from static, internal-domain dynamic, and client-domain dynamic dependency graphs, the graph superimposition, and the comparisons from the impact analysis,

as discussed hereinabove, which reveal a comprehensive view of all dependencies identified within the one or more client workflows.

In another example, shown in the graphical user interface **900** of FIG. **9**, the impact analysis menu option **708** of the pop-up menu **706** in FIG. **9** can be selected to cause display of an impact analysis report, such as a graphical representation of identified methods and their relative dependencies, as identified based on the impact analysis methods discussed herein. In response to such a selection from FIG. **9**, a first selectable node **1002** is presented in FIG. **10** that represents the particular method selected from the code as well as one or more other selectable nodes **1004**, **1006**, and **1008** that represent one or more upstream and/or downstream method dependencies of the selected particular method. Further, for example, when the first selectable node **1002** is selected in FIG. **10**, the pop-up menu **706** with a density analysis menu option **1014** for performing a density analysis may be displayed for selection, as shown in the graphical user interface **1100** of FIG. **11**. In response to a selection of the density analysis menu option **1014** for the selected node/method, a density analysis can be performed and/or density analysis results can be automatically displays in a graphical user interface **1200**, as shown in FIG. **12**. In FIG. **12**, the defect density report for the selected node/method provides an overview of specific method dependencies for the selected node/method (e.g., the quantity of upstream methods that can be used to call the selected node/method, and the quantity of downstream methods that can be called by the selected node/method, relative to other methods in the workflow).

In further aspects of the graphical user interface(s) discussed above, one or more subsequent selections of a selectable node representing a second method that is upstream or downstream from the first method may be received. In response to the subsequent selection of a selectable node representing the second method, an updated display of the impact analysis report is automatically presented. The updated display of the impact analysis report may be specific to the first method and the second method, such that the updated impact analysis report identifies at least one of another upstream dependency relationship and/or another downstream dependency relationship of a third method relative to the second method, shown as one or more additional selectable nodes that are added to the impact analysis displayed in the graphical user interface. Each of the selectable nodes may include a displayed or displayable identifier that corresponds to a method and/or code for a method.

For example, FIG. **13** depicts a graphical user interface **1300** having the first selectable node **1002** representing the method selected with another pop-up menu **1012**, the pop-up menu **1012** having an upstream impact analysis menu option **1016** for performing and/or reporting on an upstream impact analysis on the first selectable node **1002**/corresponding method. In response to the selection of the upstream impact analysis menu option **1016**, the graphical user interface **1000** is updated to include the results of the upstream impact analysis for the first selectable node **1002**. As shown in the graphical user interface **1400** of FIG. **14**, an updated impact analysis report is displayed with additional upstream nodes (e.g., node **1018**) that represent additional upstream methods in the client workflow, for example.

Additionally, in response to the selection of a second selectable node **1008** (e.g., corresponding to a method "CLocationUtility::GetMostSpecificLocation") from the updated impact analysis report of FIG. **14** where the second selectable node **1008** is located upstream from the first selectable node **1002** (i.e., meaning that, in the client workflow of the code base, the method represented by the second selectable node **1008** calls the method represented the first selectable node **1002**), the impact analysis report with selectable nodes representing dependences is updated again. For example, the graphical user interface **1500** if FIG. **15** displays an updated impact analysis report, which has been expanded to include several additional nodes (e.g., nodes **1020**, **1022**, **1024**, **1026**) representing upstream dependencies for the method represented by the second selectable node **1008** that was selected. Accordingly, the graphical user interfaces described herein are user interactive to allow expansion and contraction of method dependencies displayed, both upstream and downstream, as identified for the client workflows through impact analysis. This enables a user to view the comprehensive knowledge of all of the upstream and downstream dependencies identified between various methods in a client workflow, and each selected method, to view and identify other specific methods that will be affected when the selected method is modified in the code of the code base, for example. As such, the graphical user interfaces of the impact analysis can reveal and present exactly which methods will be affected by modifications to a method selected from the code shown in FIG. **9**, for a client workflow and based on the identified dependencies.

Impact Prediction

FIG. **16** is a block diagram of a system **1600** for impact prediction based on historical code modification, in accordance with aspects herein. In various aspects, the system **1600** includes a modification request receiving module **1602**, a feature tracking module **1604**, and a recommendation engine module **1606**. The system **1600** may further include one or more of the components in the system **100** of FIG. **1**, for example, such as the graphical user interface module **110**. In some aspects, the system **100** of FIG. **1** is utilized in tandem with, or is integrated with, the system **1600** of FIG. **16**.

In the system **1600**, the modification request receiving module **1602** is configured to receive a current request to modify a first method, in aspects. The modification request receiving module **1602** may receive multiple requests to modify any number of methods over time, such that one or more prior requests may be have been received to modify a plurality of various methods, in aspects. The feature tracking module **1604** is configured to track a modification made to the first method by the current request. Further, for one or more prior requests, the feature tracking module **1604** may have tracked each of many prior modifications made to any number of methods for prior requests. As such, the modification request receiving module **1602** may receive requests in a sequence and the feature tracking module **1604** may track the specific modifications and the methods modified within each request received in sequence over a period of time.

The system **1600** further includes, in various aspects, a recommendation engine module **1606**. The recommendation engine module **1606** identifies at least a second method that was modified by at least one of the one or more prior requests that include a prior modification made to the first method, in aspects. In some aspects, the recommendation engine module **1606** determines a score of the second method, and based on the score, identifies that the second method is predicted to be affected by the modification made to the first method by the current request. The recommendation engine module **1606** may provide the recommendation that identifies at least the second method and that

indicates the second method is predicted to be affected by the modification made to the first method by the current request. Finally, the system may include a graphical user interface module (not shown in FIG. **16**) that causes the recommendation to be displayed in a graphical user interface.

Having described the system **1600** and components thereof, it will be understood by those of ordinary skill in the art that system **1600** is but one example of a suitable system and is not intended to limit the scope of use or functionality of the present invention. Similarly, system **1600** should not be interpreted as imputing any dependency and/or any requirements with regard to each component and combination(s) of components illustrated in FIG. **16**. It will be appreciated by those of ordinary skill in the art that the arrangement and/or integrated placement of components illustrated in FIG. **16** are examples, and other methods, hardware, software, components, and devices for establishing direct, indirect, local, and/or remote communication links between the components may be utilized in implementations of the present invention. It will be understood to those of ordinary skill in the art that the components may be connected in various manners, hardwired or wireless, and may use intermediary components that have been omitted or not included in FIG. **16** for simplicity's sake. Further, it will be understood that the components of the system **1600** may communicate with each other directly or, for example, indirectly via a network, including one or more of a telecommunication network, a local area network (LANs), a wide area network (WANs), and/or a peer-to-peer-network, though not shown. Such networking environments may include campus-wide or enterprise-wide computer networks, intranets, and the Internet.

Further, the absence of components from FIG. **16** should not be interpreted as limiting the present invention to exclude additional components and combination(s) of components. Moreover, though components are represented in FIG. **16** as singular components, it will be appreciated that some aspects may include a plurality of devices and/or components such that FIG. **16** should not be considered as limiting the number of any device(s) or component(s) depicted. It should be understood that any number of components shown in FIG. **16** may be employed within the system **1600** within the scope of the present invention. Each may be implemented via a single device or multiple devices cooperating in a distributed environment.

Turning to FIGS. **17** and **18**, methods are discussed that can be performed via one or more of the components and component interactions previously described in FIG. **16**. As such, the methods are discussed briefly for brevity, though it will be understood that the previous discussion and details described therein can be applicable to aspect of the methods of FIGS. **17** and **18**. Additionally or alternatively, it will be understood that the methods discussed herein can be implemented or performed via the execution of computer-readable instructions stored on computer readable media, by one or more processors. In some aspects, the methods can be computer-implemented methods. In one aspect, one or more non-transitory computer-readable storage media having computer-readable instructions or computer-readable program code portions embodied thereon, for execution via one or more processors, can be used to implement and/or perform the methods. For example, computer-readable instructions or computer-readable program code portions can specify the performance of the methods, can specify a sequence of steps of the methods, and/or can identify particular component(s) of a software and/or hardware for performing one or more of the steps of the methods, in aspects.

FIG. **17** depicts a flow diagram showing a method **1700** for impact prediction based on historical code modifications, in accordance with aspects herein. At block **1702**, a current request to modify a first method in received. In some aspects, the modification request receiving module **1602** of FIG. **16** receives one or more prior requests to modify the first method and/or other methods, and subsequently receives the current request to modify the first method and/or other methods.

At block **1704**, a modification being made to the first method in the current request is tracked. In some aspects, the feature tracking module **1604** of the system **1600** of FIG. **16** tracks the modification(s) made to the first method and/or made to other methods for each of the current request and any prior requests. The modifications and the methods modified may be record and documents by the feature tracking module **1604**, in an aspect. Tracking the modification made to the first method in the current request can include, for example, identifying the current request (e.g., timestamp, version), identifying the first method (e.g., a specific method identifier or "name"), and identifying the particular modification that is being made to the first method in the current request. The first method may also be tagged as being modified in the current request, and the tag may include or identify the particular modification that is being made to the first method in the current request, in further aspects. In some aspects, the first method that is tagged is mapped to at least a second method and/or a plurality of other methods that were modified in one or more prior requests that also included a prior modification to the first method.

At block **1706**, at least a second method is identified that is predicted to be affected by the modification being made to the first method in the current request. In one aspect, a plurality of methods are identified, where each of the plurality of methods are predicted to be affected by the modification being made to the first method in the current request. In some aspects, the recommendation engine module **1606** predicts and identifies that at least the second method has an increased likelihood of being affected by the modification being made to the first method in the current request, for example, relative to other methods and based on prior requests that made modifications to both the first method and the second method. The second method may be predicted to be affected by the modification made to the first method in the current request by determining a score for the second method based on mapping the current request to one or more prior requests, as further discussed hereinafter. In some aspects, a lower score indicates a predicted increased likelihood of being affected by the modification made to the first method in the current request, and a higher score indicates a predicted decreased likelihood of being affected by the modification made to the first method in the current request. In an alternative aspect, a higher score indicates a predicted increased likelihood of being affected by the modification made to the first method in the current request, and a lower score indicates a predicted decreased likelihood of being affected by the modification made to the first method in the current request.

At block **1708**, a recommendation is provided that identifies the second method and that indicates the second method is predicted to be affected by the modification made to the first method in the current request. The recommendation engine module **1606** of FIG. **16**, for example, can

determine and provide the recommendation that the second method is predicted to be affected by the modification made to the first method in the current request, for example, based on the scoring and based on the prior requests that made modifications to both the first method and the second method. In further aspects, a graphical user interface is generated and displayed in order to present the recommendation.

FIG. **18** is a flow diagram showing a method **1800** for impact prediction based on historical code modifications, in accordance with aspects herein. The method **1800** is discussed with brevity, as aspects herein have been discussed above with regards to FIGS. **16** and **17**. At block **1802**, a current request to modify a first method is received. At block **1804**, the modification made to the first method by the current request is tracked. In some aspects, tracking a modification made to the first method in the current request includes identifying that the first method is being modified in the current request. In the current request, the first method identified as being modified may be tagged, in aspects. FIG. **19** is a simplified graphic diagram **1900** that depicts an example of feature tracking for impact prediction, in accordance with aspects herein. At block **1806**, at least a second method is identified that was modified by at least one of the one or more prior requests that also include a prior modification made to the first method. For example, a plurality of prior requests that modified the same first method may be identified. The prior requests may also include prior modification to other methods, in the example. In such an example, the first method that has been tagged can be mapped at least one of a plurality of methods that were previously modified in prior requests, for example. The second method may be one of the plurality of methods, in such aspects.

In one example, the current request for the first method can be compared to the one or more prior requests by determining that one or more prior requests include prior modifications to the first method. All of a plurality of methods that were modified in the one or more prior requests that include prior modifications to the first method may also be identified for analysis, in one aspect. In one example, a plurality of scores for all of the plurality of methods may be determined using the tracking of the prior requests, as further described herein, and the score may be used to determine that at least the second method in the plurality of methods is predicted to be affected by the modification made to the first method by the current request. The second method may have a score that, relative to the score for the remaining plurality of methods, indicates the second method has an increased likelihood of being affected by modifications to the first method, in some aspects. For example, when a plurality of prior requests indicate that the second method was modified along with the first method in 60%, 75% or 90% of those prior requests, the second method may be a score representing that the second method is predicted to be affected by changes made to the first method, based on the reoccurring co-modification in the prior requests.

Accordingly, at block **1808**, a score of the second method is determined. In some aspects, the score of the second method is determined by assigning, for each of the one or more prior requests, a binary value of one when the second method was modified by the prior request or a binary value of zero when the method was not modified by the prior request. A matrix of the binary values assigned to the second method for the one or more prior requests can be generated, in some aspects. Further, in such aspects, a total value of the second method may be calculated by summing the binary values of the matrix and normalized by multiplying the total value by a predetermined factor. The normalized total value acts as the score of the second method, in some aspects.

In further methods, for each of the plurality of methods in each of the one or more prior requests, a binary value of zero may be assigned to a method that was not modified by the prior request, whereas a binary value of one may be assigned when the method was modified by the prior request. In such a manner, a matrix may be generated for the plurality of methods that were modified or not modified in the one or more prior requests, in some aspects. A score may be calculated for each of the methods by summing the binary values respectively assigned to each of the plurality of methods for the one or more prior requests, and by multiplying the total value of a method by a normalization factor to reach the normalized total value, in one aspect. The normalized total value of each of the plurality of methods, including the second method, may then be compared to one another and ranked, for example. FIG. **20** depicts example of binary value assignment tables or matrices **2000** for method modifications in prior requests that are used for impact prediction, in accordance with aspects herein. For example, multiple requests (e.g., **100**, **200**, **300**, **400**, etc., where NEW CR is the current request) for multiple methods (e.g., F_1, F_2, F_3, etc.) have been tracked and assigned a binary value that indicates whether the particular method was modified in that particular request, as shown in the top left table of FIG. **20**. Further, one or more prior requests that included a modification to the first method are identified by mapping the NEW CR to the one or more prior requests, as shown in the bottom middle table of FIG. **20**. These other methods that were modified in each of the prior requests alongside the first method are identified and used to predict which of those other methods may be impacted or affected by the modification to the first method in the current request, in aspects.

At block **1810**, based on the score of the second method, the second method is identified as being predicted to be affected by the modification of the first method by the current request. For example, the normalized total value of each of the plurality of methods, including the second method, may be compared to one another. In such an example, one or more of the methods, including the second method, may be selected as being predicted to be affected by the modification made to the first method by the current request because of the methods' respective scores. In some aspects, the second method is identified and selected for recommendation when, for example, a threshold is met by the score of the second method and/or the score of the second method is greater than the score of the other methods. In some aspects, multiple methods are selected for recommendation in order of greatest likelihood of being affect by the modification made to the first method by the current request. Based on the summing and normalization, a lower score indicates a predicted increased likelihood of being affected by the modification made to the first method in the current request, and wherein a higher score indicates a predicted decreased likelihood of being affected by the modification made to the first method in the current request.

At block **1812**, a recommendation is provided that identifies at least the second method and that indicates the second method is predicted to be affected by the modification made to the first method by the current request. The recommendation may be provided in a graphical user interface, in some aspects. FIG. **21** depicts a graphical user interface **2100** with a pop-menu option **2102** for impact prediction, such that a user may input the current request to modify the first

method. The pop-up menu **2106** may include a recommendation menu option **2104** for selection, which is used to trigger a recommendation for the current request. In response to selection of the recommendation menu option **2104**, the graphical user interface **2200** of FIG. **22** is used to display the impact prediction score report for the first method in the current request, in accordance with aspects herein. As shown in FIG. **22**, one or more specific methods are identified (e.g., "name") and the score for each of the specific methods are displayed, for example, in a score ascending order that represents the strength of the prediction, i.e., the likelihood that each of the recommended methods may be affected by the modification to the first method in the current request, based on historical modifications of the prior requests.

Turning now to FIG. **23**, a diagram of a computing environment **2300** that is suitable to implement aspects described hereinabove is depicted. It will be understood by those of ordinary skill in the art that the computing environment **2300** is just one example of a suitable computing environment and is not intended to limit the scope of use or functionality of the present invention. Similarly, the computing environment **2300** should not be interpreted as imputing any dependency and/or any requirements with regard to each component and combination(s) of components illustrated in FIG. **23**. It will be appreciated by those having ordinary skill in the art that the connections illustrated in FIG. **23** are also exemplary as other methods, hardware, software, and devices for establishing a communications link between the components, devices, systems, and entities, as shown in FIG. **23**, may be utilized in implementation of the present invention. Although the connections are depicted using one or more solid lines, it will be understood by those having ordinary skill in the art that the exemplary connections of FIG. **23** may be hardwired or wireless, and may use intermediary components that have been omitted or not included in FIG. **23** for simplicity's sake. As such, the absence of components from FIG. **23** should be not be interpreted as limiting the present invention to exclude additional components and combination(s) of components. Moreover, though devices and components are represented in FIG. **23** as singular devices and components, it will be appreciated that some aspects may include a plurality of the devices and components such that FIG. **1** should not be considered as limiting the number of a device or component.

Continuing, the computing environment **2300** of FIG. **23** is illustrated as being a distributed environment where components and devices may be remote from one another and may perform separate tasks. The components and devices may communicate with one another and may be linked to each other using a network **2302**. The network **2302** may include wireless and/or physical (e.g., hardwired) connections. Exemplary networks include a telecommunications network of a service provider or carrier, Wide Area Network (WAN), a Local Area Network (LAN), a Wireless Local Area Network (WLAN), a cellular telecommunications network, a Wi-Fi network, a short range wireless network, a Wireless Metropolitan Area Network (WMAN), a Bluetooth® capable network, a fiber optic network, or a combination thereof. The network **2302**, generally, provides the components and devices access to the Internet and web-based applications.

The computing environment **2300** comprises a computing device **2304** in the form of a server. Although illustrated as one component in FIG. **23**, the present invention may utilize a plurality of local servers and/or remote servers in the computing environment **2300**. The computing device **2304** may include components such as a processing unit, internal system memory, and a suitable system bus for coupling to various components, including a database or database cluster. The system bus may be any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, and a local bus, using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronic Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI) bus, also known as Mezzanine bus.

The computing device **2304** may include or may have access to computer-readable media. Computer-readable media can be any available media that may be accessed by the computing device **2304**, and includes volatile and nonvolatile media, as well as removable and non-removable media. By way of example, and not limitation, computer-readable media may include computer storage media and communication media. Computer storage media may include, without limitation, volatile and nonvolatile media, as well as removable and non-removable media, implemented in any method or technology for storage of information, such as computer-readable instructions, data structures, program modules, or other data. In this regard, computer storage media may include, but is not limited to, Random Access Memory (RAM), Read-Only Memory (ROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), flash memory or other memory technology, CD-ROM, digital versatile disks (DVDs) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage, or other magnetic storage device, or any other medium which can be used to store the desired information and which may be accessed by the computing device **2304**. Computer storage media does not comprise signals per se.

Communication media typically embodies computer-readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism, and may include any information delivery media. As used herein, the term "modulated data signal" refers to a signal that has one or more of its attributes set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency (RF), infrared, and other wireless media. Combinations of any of the above also may be included within the scope of computer-readable media.

In aspects, the computing device **2304** uses logical connections to communicate with one or more remote computers **2306** within the computing environment **2300**. In aspects where the network **2302** includes a wireless network, the computing device **2304** may employ a modem to establish communications with the Internet, the computing device **2304** may connect to the Internet using Wi-Fi or wireless access points, or the server may use a wireless network adapter to access the Internet. The computing device **2304** engages in two-way communication with any or all of the components and devices illustrated in FIG. **23**, using the network **2302**. Accordingly, the computing device **2304** may send data to and receive data from the remote computers **2306** over the network **2302**.

Although illustrated as a single device, the remote computers **2306** may include multiple computing devices. In an aspect having a distributed network, the remote computers

2306 may be located at one or more different geographic locations. In an aspect where the remote computers **2306** is a plurality of computing devices, each of the plurality of computing devices may be located across various locations such as buildings in a campus, medical and research facilities at a medical complex, offices or "branches" of a banking/credit entity, or may be mobile devices that are wearable or carried by personnel, or attached to vehicles or trackable items in a warehouse, for example.

In some aspects, the remote computers **2306** is physically located in a medical setting such as, for example, a laboratory, inpatient room, an outpatient room, a hospital, a medical vehicle, a veterinary environment, an ambulatory setting, a medical billing office, a financial or administrative office, hospital administration setting, an in-home medical care environment, and/or medical professionals' offices. By way of example, a medical professional may include physicians; medical specialists such as surgeons, radiologists, cardiologists, and oncologists; emergency medical technicians; physicians' assistants; nurse practitioners; nurses; nurses' aides; pharmacists; dieticians; microbiologists; laboratory experts; genetic counselors; researchers; veterinarians; students; and the like. In other aspects, the remote computers **2306** may be physically located in a non-medical setting, such as a packing and shipping facility or deployed within a fleet of delivery or courier vehicles.

Continuing, the computing environment **2300** includes a data store **2308**. Although shown as a single component, the data store **2308** may be implemented using multiple data stores that are communicatively coupled to one another, independent of the geographic or physical location of a memory device. Exemplary data stores may store data in the form of artifacts, server lists, properties associated with servers, environments, properties associated with environments, computer instructions encoded in multiple different computer programming languages, deployment scripts, applications, properties associated with applications, release packages, version information for release packages, build levels associated with applications, identifiers for applications, identifiers for release packages, users, roles associated with users, permissions associated with roles, workflows and steps in the workflows, clients, servers associated with clients, attributes associated with properties, audit information, and/or audit trails for workflows. Exemplary data stores may also store data in the form of electronic records, for example, electronic medical records of patients, transaction records, billing records, task and workflow records, chronological event records, and the like.

Generally, the data store **2308** includes physical memory that is configured to store information encoded in data. For example, the data store **2308** may provide storage for computer-readable instructions, computer-executable instructions, data structures, data arrays, computer programs, applications, and other data that supports the functions and action to be undertaken using the computing environment **2300** and components shown in exemplary FIG. **23**.

In a computing environment having distributed components that are communicatively coupled via the network **2302**, program modules may be located in local and/or remote computer storage media including, for example only, memory storage devices. Aspects of the present invention may be described in the context of computer-executable instructions, such as program modules, being executed by a computing device. Program modules may include, but are not limited to, routines, programs, objects, components, and data structures that perform particular tasks or implement particular abstract data types. In aspects, the computing device **2304** may access, retrieve, communicate, receive, and update information stored in the data store **2308**, including program modules. Accordingly, the computing device **2304** may execute, using a processor, computer instructions stored in the data store **2308** in order to perform aspects described herein.

Although internal components of the devices in FIG. **23**, such as the computing device **2304**, are not illustrated, those of ordinary skill in the art will appreciate that internal components and their interconnection are present in the devices of FIG. **23**. Accordingly, additional details concerning the internal construction device are not further disclosed herein.

The present invention has been described in relation to particular aspects, which are intended in all respects to be illustrative rather than restrictive. Further, the present invention is not limited to these aspects, but variations and modifications may be made without departing from the scope of the present invention.

What is claimed is:

1. One more non-transitory computer-readable media having computer-executable instructions embodied thereon that when executed perform a method to predict additional methods that may be affected by modification to another method based on historical modifications, the media comprising:

receiving a current request to modify a first method;

tracking a modification made to the first method in the current request;

identifying at least a second method that is predicted to be affected by the modification made to the first method in the current request;

determining a score of the second method by:

for each of the one or more prior requests, assigning a binary value of one when the second method was modified by the prior request or a binary value of zero when the second method was not modified by the prior request;

generating a matrix that contains the binary values assigned to the second method for the one or more prior requests; and

calculating a total value as the score of the second method by summing the binary values of the matrix; and

based on the score of the second method, generating a graphical user interface that provides a recommendation that identifies the second method and that indicates the second method is predicted to be affected by the modification made to the first method in the current request.

2. The media of claim **1**, wherein tracking the modification made to the first method in the current request comprises:

identifying the modification made to the first method in the current request.

3. The media of claim **2**, wherein tracking the modification made to the first method in the current request comprises:

tagging the first method as being modified in the current request.

4. The media of claim **3**, wherein tracking the modification made to the first method in the current request comprises:

mapping the first method that is tagged to at least the second method, wherein the second method was modified in a prior request that included a prior modification made to the first method.

5. The media of claim **4**, further comprising:

determining a score for the second method of the prior request based on the mapping.

6. The media of claim **5**, wherein a lower score indicates a predicted increased likelihood of being affected by the modification made to the first method in the current request, and wherein a higher score indicates a predicted decreased likelihood of being affected by the modification made to the first method in the current request.

7. One more non-transitory computer-readable media having computer-executable instructions embodied thereon that, when executed, perform a method to predict additional methods that may be affected by modification to another method based on historical modifications, the media comprising:

receiving a current request to modify a first method;

tracking a modification made to the first method by the current request;

identifying at least a second method that was modified by at least one of the one or more prior requests that include a prior modification made to the first method;

determining a score of the second method by:

for each of the one or more prior requests, assigning a binary value of one when the second method was modified by the prior request or a binary value of zero when the second method was not modified by the prior request;

generating a matrix that contains the binary values assigned to the second method for the one or more prior requests; and

calculating a total value as the score of the second method by summing the binary values of the matrix;

based on the score, identifying that the second method is predicted to be affected by the modification made to the first method by the current request; and

generating a graphical user interface that provides a recommendation that identifies at least the second method and that indicates the second method is predicted to be affected by the modification made to the first method by the current request.

8. The media of claim **7**, wherein tracking the modification made to the first method in the current request comprises:

identifying that the first method is being modified in the current request.

9. The media of claim **7**, wherein tracking the modification made to the first method in the current request comprises:

tagging, in the current request, the first method identified as being modified.

10. The media of claim **7**, wherein identifying at least the second method that was modified in the one or more prior requests that include the prior modification made to the first method comprises:

mapping the first method that is tagged to a plurality of methods, wherein the at least one of the plurality of methods was modified by the one or more prior requests, and wherein the second method is included in the plurality of methods.

11. The media of claim **7**, wherein determining the score of the second method comprises:

multiplying the total value of the method by a predefined factor to normalize the total value of the second method, wherein the total value that is normalized is the score of the second method.

12. The media of claim **7**, further comprising:

determining that a threshold is met by the score of the second method.

13. The media of claim **7**, wherein a lower score indicates a predicted increased likelihood of being affected by the modification made to the first method in the current request, and wherein a higher score indicates a predicted decreased likelihood of being affected by the modification made to the first method in the current request.

14. The media of claim **7**, wherein comparing the current request for the first method to the one or more prior requests comprises:

determining that the one or more prior requests include prior modifications to the first method in the current request;

identifying all a plurality of methods that were modified in the one or more prior requests that include prior modifications to the first method;

determining a plurality of scores for all of the plurality of methods that were modified in the one or more prior requests that include prior modifications to the first method;

based on the plurality of scores for all of the plurality of methods relative to each other, determining that at least the second method in the plurality of methods is predicted to be affected by the modification made to the first method by the current request; and

determining to include the second method in the recommendation.

15. A system for a predicting additional methods that may be affected by modification to another method based on historical modifications, the system comprising:

one or more processors;

a tracking feature module that:

receives a current request to modify a first method; and

tracks a modification made to the first method by the current request;

a recommendation engine module that:

identifies at least a second method that was modified by at least one of the one or more prior requests that include a prior modification made to the first method;

determines a score of the second method by;

for each of the one or more prior requests, assigning a binary value of one when the second method was modified by the prior request or a binary value of zero when the second method was not modified by the prior request;

generating a matrix that contains the binary values assigned to the second method for the one or more prior requests; and

calculating a total value as the score of the second method by summing the binary values of the matrix;

based on the score, identifies that the second method is predicted to be affected by the modification made to the first method by the current request; and

provides a recommendation that identifies at least the second method and that indicates the second method is predicted to be affected by the modification made to the first method by the current request; and

a graphical user interface module that causes the recommendation to be displayed in a graphical user interface.

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